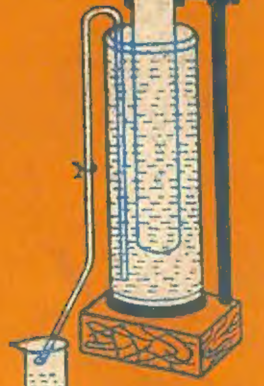
A NEW APPROACH to PRACTICAL PHYSICS



S. B. SINGH

ARYA BOOK DEPOT
KAROL BAGH, NEW DELHI-5

A NEW APPROACH
to
PRACTICAL PHYSICS

(DEMONSTRATION AND PUPIL'S EXPERIMENTS AND ACTIVITIES)

(Based on the syllabus for IX and X classes under the 10+2+3 pattern of education for secondary schools)

by

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PREFACE

Science has influenced man's life to an amazing extent. The children too are much affected by the tremendous progress that the science has brought out. They use synthetic fibres, medicines and other things in daily life which were unknown to their parents when they were young. So the study of science and its *products* is exremely important to the very young children. Keeping this fact in view the Education Ministry rightly introduced the compulsory Science Education upto 10th class in the new **10+2+3** pattern of education.

A young mind is exposed to enormous scientific events in daily life such as working of a hand pump, bicycle, pressure cooker, buses and electrical appliances like iron press, fans, radio etc. Study of such like events falls within the purview of an extremely important branch of science called **Physics**. The study of science in general and that of physics in particular cannot be fruitful without doing *Experiments*. A person may claim to be a perfect swimmer simply after reading all the books he can get on the subject of swimming but his swimming capability can be tested only after he enters the deep water. In a like manner in sciences, **'theory only predicts but experiment decides'**. Seeing experiments performed (*i.e.*, demonstration experiments) or better still being able to do them yourself (*i.e.*, pupil's experiments) is of the greatest importance in understanding the methods and principles of science.

The motivation for the author for writing this book has sprung from his close association with the training programme for the school teachers in physics on the lines of the new 10+2+3 pattern of Education. In fact the author delivered a series of lectures with the help of demonstration experiments designed by his ownself. Non-availability of the sufficient literature for the various categories of experiments in physics introduced for IX and X classes was felt very much by all the participants in the training programme. Essentially this feeling of the participants inspired the author for the humble attempt of writing of this book.

Following are the salient features of the book.

1. The experiments introduced in the IX and X classes syllabus of this new scheme of studies have been divided into four categories *viz.*, demonstration experiments, pupil's experiments, pupil's activity and group activity. This is the first book of its kind which contains all the experimental details of these experiments. At the end of the book, chapters on the "elements of soldering" and "elementary training in workshop practice" are also included which form a part of the group activity in the X class.

2. Special care has been taken to suggest alternative experiments so as to suit the varied class-room conditions of different schools. It is hoped that even a school in a remote village with inadequate laboratory facilities will find in the book some experiments suggested which can be performed with the materials which may be procured by them easily.

3. At the beginning of each chapter, important points under the heading '*Points to Remember*' have been given so that the students also clearly understand the *theory* underlying the experiments. To help the students to test their understanding, objective type questions are also given at the end of each chapter. Specimen **Viva—Voce** questions are given for the experiments which fall in the catagory of "pupil's experiment." These are the usual type of "Oral questions" asked at the time of practical examinations.

Suggestions from teachers and readers for improving the book will be gratefully received.

February, 1976. S.B. Singh.

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ON THE LEFT HAND PAGE OF THE RECORD BOOK

(To be written in pencil or ink)

(1) **Date**

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(3) **Apparatus**

(4) **Diagram**

(5) **Observation.** : Observations are the heart of the experiment. These should be recorded in the tabular form.

(6) **Calculation**

(7) **Result** : Result should always be mentioned with proper units. Also the physical quantities like temperature, pressure etc. should also be mentioned if the result depends upon them.

(8) **Precautions**

ON THE RIGHT HAND PAGE OF THE RECORD BOOK

(To be written in ink)

(1) **Date**

(2) **Experiment**

(3) **Theory**

(4) **Procedure**

(5) **Conclusion**

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PART I

For Class IX

CHAPTER

1. Screw and Screw-Jack
2. Centre of Gravity and Equilibrium
3. Couple
4. Banking of Curves
5. Sound
6. Properties of Matter
7. Model of our Solar System
8. Velocity and Acceleration
9. Balance and Weighing
10. Wet and Dry Bulb Hygrometer

TO THE PUPILS

A person may read all the books he can get on the practical subject say of playing cricket, but he will never learn this game until he goes to the field, handles the bat and faces a ball. A young girl also cannot prove to be a good cook by simply reading books on cookery until she *practices* preparing actual dishes in the kitchen.

In like manner, seeing experiments performed (demonstration experiments) or better still, being able to do experiment yourself is of the greatest importance in understanding principles and methods of science.

History of Science tells us that most of the notable discoveries in science have been made in a laboratory. So, for a systematic scientific training of a young mind a genuine laboratory practice is needed. Before starting an experiment in the laboratory, a student should follow the **General Instructions** as given below :

(i) **Preparation for the Experiment.** Before starting the experiment, the student must be crystal clear about the aim of the experiment that is *what* he is going to show by the experiment. As a second step he should also be clear *how* it can be done and what are the various pieces of apparatus needed for the purpose.

(ii) **Performing the Experiment.** Arrange the apparatus for the particular experiment carefully according to the instructions for that experiment either given by the teacher or given in a good physics practical book. Now perform the experiment observing the precautions necessary for the success of the experiment.

(iii) **Writing the Experiment in the Record Book.** A neat and systematic writing of the experiment in the laboratory record book or file is equally important in achieving the success of the experiment. The students may write the experiment in the following manner.

1

Screw & Screw Jack

§1.01. Points to Remember

(1) A **Machine** is a device by means of which a force applied at one point may be used to overcome another force applied at some other point.

(2) In mechanics, there are six *simple machines*. These are the **Lever**, the **Pulley**, the **Wheel** and **Axle**, the **Inclined Plane**, the **Screw** and the **Wedge**. Other machines which we come across, are either modifications of these *simple machines* or combination of two or more of them.

(3) **Effort :** It is the force applied to a machine.

(4) **Load :** It is the force against which a machine does work.

(5) **Mechanical Advantage** $(\mathbf{M.A.}) = \dfrac{\textbf{Load}}{\textbf{Effort}}$.

(6) **Velocity Ratio** $= \dfrac{\text{Distance moved by the effort}}{\text{Distance moved by the load in the same time}}$.

(7) **Efficiency** $= \dfrac{\text{Useful work done by a machine}}{\text{Total work put into the machine}} \times 100\%$.

(8) **Efficiency** $= \dfrac{\textbf{Mechanical Advantage (M.A.)}}{\textbf{Velocity Ratio (V.R.)}} \times 100\%$.

§1.02. Screw

It is a *simple machine* which may be regarded as an inclined plane wound on a cylinder. Screws are normally made of metal. Fig. 1.2(a) represents a *screw* (also called **Bolt)** B through a *nut* Ns B is a cylindrical piece of metal having a helical groove cut in it, thu. leaving a projecting screw *thread*. A screw may be a single threaded or multi-threaded. Fountain pens usually have three threads. Threads of screws in common use are *triangular* or V-shaped as represented in Fig. 1.2(b). H is called the *head* of the screw. Screws are schemati

cally represented as in Fig. 1.2(*c*). The *distance* (parallel to the axis) *between two consecutive threads is called the pitch* (p) of the screw. In

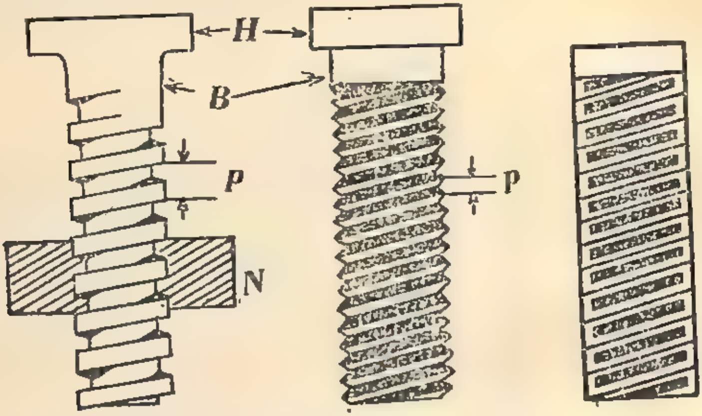


Fig. 1.2. Screw. (*a*) Square threaded screw. (*b*) Triangular (V-shaped) threaded screw. (c) Screw representation.

the case of a single threaded screw, *pitch is equal to the* **axial distance** *moved by the screw when its head is given one complete rotation.*

§1.03. Demonstration Experiment No. 1

Aim. To demonstrate the relation between a screw and an inclined plane.

Apparatus. A cylindrical pencil, a sheet of plane paper, a scissors or a blade and an actual screw.

Procedure. (*i*) Cut the paper sheet with scissors or blade in the form of a right triangle to have an inclined plane as shown in Fig. 1.3(*b*).

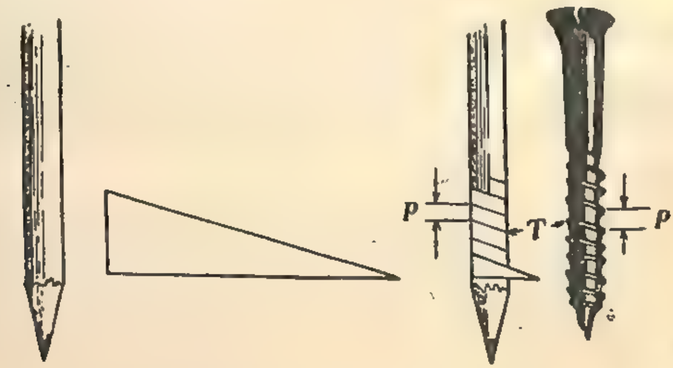


Fig. 1.3. Relation between a screw and an inclined plane. (*a*) Pencil (*b*) Inclined plane. (*c*) Inclined plane wound on the pencil. (*d*) Actual screw.

(*ii*) Wind the inclined plane paper on the pencil as shown in Fig. 1.3(*c*).

(*iii*) Now compare the different layers of the paper wound on the pencil with actual threads of the screw which is shown in Fig. 1.3(*d*). The slant lines of the layers [Fig. 1.3(*c*)] represent the **thread** T of the screw and the distance between two consecutive lines represents the **pitch** p.

Conclusion. The above observations [Fig. 1.3(*c*)] reveal that **a screw** may be regarded as an ***inclined plane*** wound on a cylinder.

§1.04. Screw-Jack

It is a machine based on the principle of screw. Screw-jack is used for lifting loads like automobiles, *i.e.*, car, truck etc.

Construction. Screw-jack consists of a hollow metal case A with a flat and heavy base (*see* Fig. 1.4). The case A has a hole H,

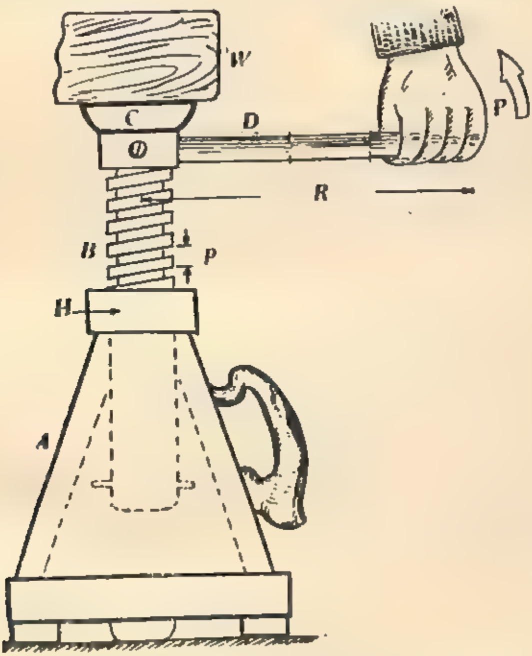


Fig. 1.4. Screw-Jack.

the inner side of which is threaded to receive the square threaded screw B. The load W, to be lifted, rests on the collar C which is fitted on the screw head. The purpose of the *collar C is to prevent the load from rotating with the screw head.** The screw is rotated with a strong metal bar D which is slided inside a hole made in the screw head.

* Rotation of the load may also be avoided by attaching the bar D to the nut H of the Screw-Jack. Thus the screw head has only a linear motion.

Theory. Let the load W on the collar C (Fig. 1.4) be lifted by applying a force P (effort force) on the rod D such that its point of application is at a distance of R from the axis of the screw. Also let us suppose that the effort P is acting in a horizontal plane and perpendicular to the length R of the rod D. For one complete rotation of the screw by the effort P, the axial distance moved by the screw is equal to its pitch 'p'. Thus

Work done by the effort $= P \cdot 2\pi R$

and Work done on the load $= W \cdot p$

Assuming no wastage of energy due to rubbing of the screw, we can write

$$W \cdot p = P \cdot 2\pi R$$

$$\therefore \quad \frac{W}{P} = \text{Mechanical advantage} = \frac{2\pi R}{p} \qquad \ldots(1)$$

$$\text{But} \quad \frac{2\pi R}{p} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load in the same time}}$$

$$\text{or} \quad \frac{2\pi R}{p} = \text{Velocity Ratio (V.R.)}$$

$$\therefore \quad \text{M.A.} = \text{V.R.} \qquad \text{[Under ideal conditions of no friction]}$$

Equation (1) suggests that for larger mechanical advantage, arm R should be large and the pitch p should be small.

However, in actual practice, on account of rubbing between the screw and its nut some friction is inevitable and so the *useful work obtained is always less than the work that should be got out from a screw without any friction.*

Thus the mechanical advantage (W/P) of a screw-jack is always less than its velocity ratio ($2\pi R/p$). Therefore, the efficiency of a screw-jack is always less than 100%.

§1.05. Demonstration Experiment No. 2

Aim. To demonstrate the working of a screw-jack and to determine its M.A., V.R., and efficiency.

Apparatus. A screw-jack, three pulleys, two hangers and weights, strong string, bricks or stone pieces of different weights to act as loads and a balance.

Procedure. (1) Let a student sit on the screw jack and raise himself by pushing the arm D (*see* Fig. 1.4) of the screw-jack with one finger.

(2) Remove the arm D from the screw-jack and replace it by a suitable pulley P_1 of a large diameter and with grooved rim as shown in Fig. 1.5.

(3) Wind two strings round the rim of the grooved pulley P_1 and pass them over two other pulleys P_2 and P_3 as shown in Fig. 1.5. Attach the hangers to the other ends of these strings.

(4) Put on the load W on the screw-jack. Now place on the hangers some known equal weights. Go on adding equal weights

on both the hangers till the hangers just start moving down. Note this value of the weights. Value of this weight is the effort P. Remove the weight W from the screw-jack and weigh it on a balance.

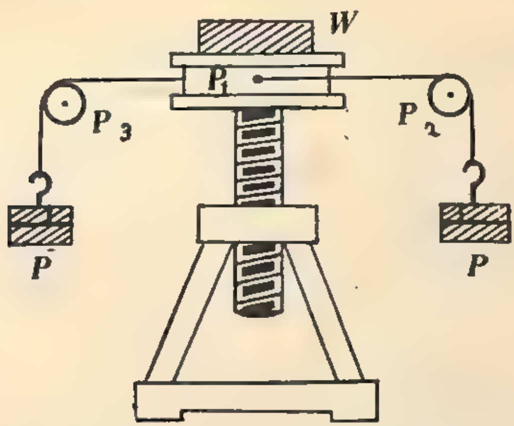


Fig. 1.5. Screw-Jack modified for determining its M.A., etc.

(5) Take a series of observations for different loads W.

(6) Measure the diameter of the pulley P_1. Also measure the pitch p of the screw-jack with the help of the upper jaws of a vernier callipers.

(7) Record the observations as tabulated below :

(i) Diameter of the pulley $P_1 = 12''$

(ii) Pitch of the screw $= 0{\cdot}5''$

S. No.	*W*	*P (including the weight of the hanger)*
1.	5·00 kg. wt.	0·160 kg. wt.
2.	...	...
3.	...	...
4.	...	...

Calculations :

$$\text{M.A.} = \frac{W}{P} = \frac{5{\cdot}00}{0{\cdot}16} = 31{\cdot}1$$

$$\text{V.R.} = \frac{2\pi(12/2)}{0{\cdot}5} = 3{\cdot}14 \times 12 \times 2 = 75{\cdot}4$$

$$\text{Efficiency} = \frac{\text{M.A.}}{\text{V.R.}} \times 100 = \frac{31{\cdot}1}{75{\cdot}4} \times 100 = 41{\cdot}3\%.$$

Result. The screw-jack has M.A.$=31 \cdot 1$
V.R.$=75 \cdot 4$ and Efficiency$=41 \cdot 3\%$.

Conclusion. It is obvious from the result that for any screw-jack :

(*i*) M.A. of a screw-jack is less than its V.R.

(*ii*) Efficiency of a screw-jack is much less than 100%.

QUESTIONS

1. Explain why it is easier to lift a load by moving it along an inclined plane rather than lifting it vertically.
2. For a machine why is its M.A. < V.R. ?
3. Why is an inclined plane called a machine ?
4. Is there any mechanical advantage derived from a single fixed pulley ? If not, then why is a single fixed pulley called a machine ?
5. What is the use of sharpening a blade or a knife ?
6. Pick out the correct statements from the following :
   (*a*) In general the axial distance, moved by a screw when its head is given one complete rotation, is called the pitch.
   (*b*) The axial distance moved by a single threaded screw for one complete rotation of its head is equal to its pitch.
   (*c*) M.A. of a screw-jack is larger if its pitch is larger.
   M.A. of a screw-jack is larger if its pitch is smaller.
   (*e*) the collar of the head of a screw-jack protects the screw.
   (*f*) The collar of a screw-jack provides a large base to place the load.
   (*g*) The collar of a screw-jack prevents the rotation of the load with the screw
7. A railway porter carrying luggage on his head on a level platform moves from one place to another. Select the correct statement from the followings :
   He is paid for :
   (*a*) doing work and spending energy.
   (*b*) not doing work but for spending energy.
   (*c*) doing nothing.

2

Centre of Gravity & Equilibrium

§2.01. Points to Remember

(1) A **Force** has three characteristics : its *magnitude*, its *direction* and its *point of application*. In the case of **Gravitational Force** on a body of mass m, its magnitude is mg, its direction is towards the centre of earth and its point of application is the **Centre of Gravity.** The **Centre of Gravity** *of a body is the point through which the whole weight of the body may be considered to act, in whatever position the body is kept.*

(2) The **Torque** or **Moment** of a force is given by the relation :

Moment=**Force**×Perpendicular distance from the fulcrum to the force.

The moment of the force acting on a body has a turning effect on it.

(3) When a lever is in **Equilibrium,** (*i.e.*, its arm is horizontal), the total clockwise moment about the fulcrum is equal to the total anti-clockwise moment.

(4) There are three kinds of the **Equilibrium** of bodies.

(*i*) **Stable Equilibrium.** A body is said to be in stable equilibrium if when displaced *slightly* and then released, it returns to the *original* position.

(*ii*) **Unstable Equilibrium.** A body is said to be in unstable equilibrium if when displaced slightly and then released, it moves *farther* from the original position.

(*iii*) **Neutral Equilibrium.** A body is said to be in neutral equilibrium if when displaced slightly and then released, it stays in the *new position.*

(5) The centre of gravity of a rigid body may be either within the body or outside the body.

§2.02. Demonstration Experiment No. 3

Aim. To demonstrate that the whole weight of a body may be considered to act at a point called the centre of gravity (C.G.).

Apparatus. A metre-scale, weights, a knife edge shaped wedge, light cotton thread and a spring balance.

Procedure. (*i*) Weigh the metre-scale *AB* with the spring balance. Let its weight be 200 gf. (*See* Fig. 2.1).

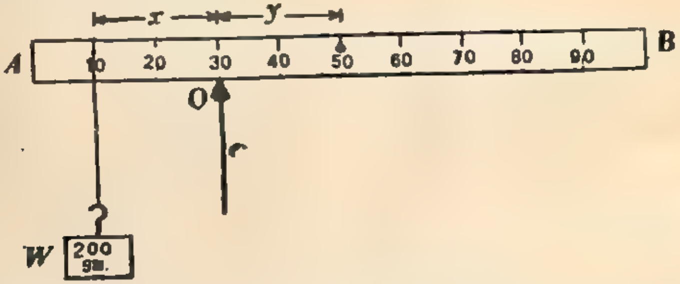


Fig. 2.1. The weight of the scale is considered to act at a point called C.G.

(*ii*) Support the metre-scale on the knife-edge *O* such that the knife-edge is somewhere towards the end *A*. For one reading let the position of *O* be 20 cm. from the centre of the scale.

(*iii*) Now attach a loop, made at one end of cotton thread, at a position of 10 cm. from the end *A*. Attach suitable weight to the other end of the thread so that the scale is balanced in the horizontal position. Note down this weight.

(*iv*) Take similar observations by changing the positions of *O*, the positions of the loop and the weight.

(*v*) Tabulate the observations as given below :

Observations. Weight of the metre-scale=200 gf.

S. No.	x	W	*Anti-clockwise moment* $=W \cdot x$	
1.	20 cm.	200 gf.	4,000 gf.	20 cm.
2.				
3.				
4.				

Calculations : First reading :

The anti-clockwise moment$=200\times 20$ gf. cm.

$=4{,}000$ gf. cm.

For the balance of the beam the clockwise moment must be equal to 4,000 gf. cm. Since no weight is attached towards the right hand side of the fulcrum O, therefore, this clockwise moment must be due to the weight of the metre scale. If the point of application of this weight is at a distance of y cm. from O towards the end B, we get

$$4{,}000 = 200 \cdot y$$

(Since the weight of the scale is 200 gf.)

$$\therefore \qquad y = 20 \text{ cm.}$$

The point whose distance is 20 cm. from O towards B is the **Mid-point of the scale**, (*i.e.*, the position 50 cm.).

Other Readings. Calculations similar to the above are made for all the readings. It will be found that in each case, the point of application of the weight of metre-scale is the same, *i.e.*, the middle point of the scale. However, if the metre-scale is not uniform, the C.G. may not be the middle point of the scale.

Conclusion. We, therefore, conclude that the metre-scale behaves as if its whole weights were concentrated at a point. In other words, the metre-scale is behaving in this experiment as if it were a light, weightless structure with all its weight concentrated at its C.G. This statement is true for any position of the fulcrum. What is true for the metre-scale in this regard is true for all bodies.

§2.03. Pupil's Activity No. 1 (*a*)

Aim. To find the C.G. of a regular or an irregular lamina* using a plumb line.

Apparatus. Plate of cardboard, metre-scale, plumb-line or thread and a weight, a stand with clamp, and a thin pin.

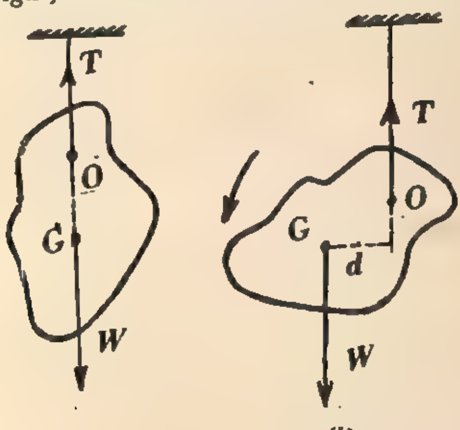


Fig. 2.2. A suspended body rests only in the position (*a*).

* A lamina is a planar body whose thickness is negligible in comparison to its length and breadth. For example, a thin metal sheet, a thin card-board, a drawing paper, a thin sheet of plywood etc.

Theory. When a body is suspended from a point O [Fig. 2.2(a)] other than its centre of gravity G, the *body comes to rest in a position such that the C.G. is vertically below the point of suspension O.* If the body is displaced from this position as shown in Fig. 2.2(b) an anti-clock moment of magnitude $W.d$ acts about the point O so as to bring the body back to the original position of Fig. 2.2(a), where the points O and G are on the same vertical line. Thus in the equilibrium position [Fig. 2.2(a)] in addition to the resultant force, the torque on the body must also be zero.

Procedure. (1) Make small holes at three positions near the periphery of the lámina and suspend it with the help of the pin and the stand as shown in Fig. 2.3.

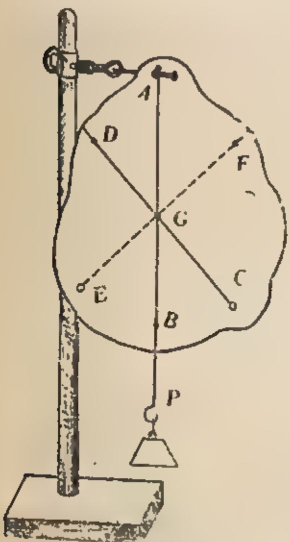


Fig. 2.3. Lamina and plumb line suspended from the same support.

(2) Suspend a plumb line P (may be made by suspending a metal piece or weight with a thread), from the same pin in front of the lamina. Mark the point B somewhere near the lower edge of the lamina just behind the plumb line thread. While doing so, care should be taken neither to disturb the lamina nor the plumb line.

(3) Remove the lamina from the stand. Join the line AB. Now suspend the lamina through another hole C and repeat step (2) to get the line CD. The centre of gravity must lie on AB and CD both and therefore it is the point of intersection of these two lines.

(4) **Checking.** Suspend the lamina through the third hole and draw line EF by following step (2). The line EF should pass through the point of intersection of the lines AB and CD.

Alternatively the accuracy of the position G may be checked by balancing the lamina at G on the tip of a pin.

Note. If the lamina is of such a shape that the centre of gravity does not lie on it (See Fig. 2.4), join AB, CD and EF with cotton thread held on by plasticine or quickfix.

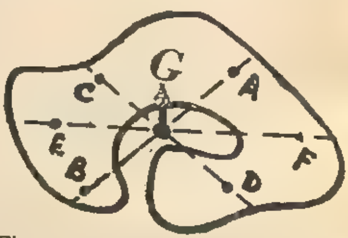


Fig 2.4. Use of cotton thread to join *AB*, *CD* and *EF*, if *G* is outside.

§2.04. Pupil's Activity No. 1(b) : Balancing Method for C.G.

The centre of gravity of long and thin objects, such as a ruler or a metal sheet of regular or irregular shape, may very conveniently be found approximately by balancing it on a long straight edge.

Procedure. (1) Balance the object (thin sheet or lamina) on a long and straight edge S as shown in Fig. 2.5(a). Mark the line of balance AB along the edge with a sharp pencil. The C.G. must lie somewhere on this line.

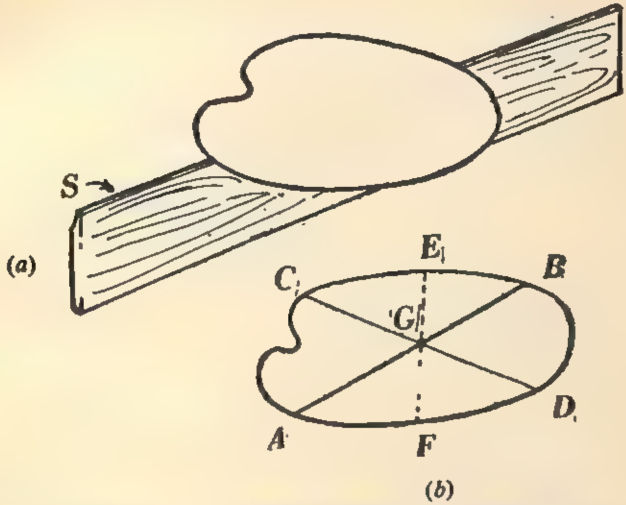


Fig. 2.5. To balance a lamina on a straight edge.

(2) Now balance the sheet in some other position and mark the balancing line CD as in step (i). The C.G. must lie on the line AB as well on CD. Therefore the point of intersection G of the lines AB and CD is the centre of gravity as shown in Fig. 2.5(b).

§2.05. Pupil's Activity No. 1(c) (Graphical Method for C.G.)

Centre of gravity of plane figures like a lamina may be located by this method provided the edges of the plane body are straight. A method for locating the C.G. of a triangular sheet [Fig. 2.6(a)] is discussed below.

Procedure. (1) Draw a series of lines parallel to BC and equally spaced, *e.g*, 1 mm. apart as shown in Fig. 2.6(b)

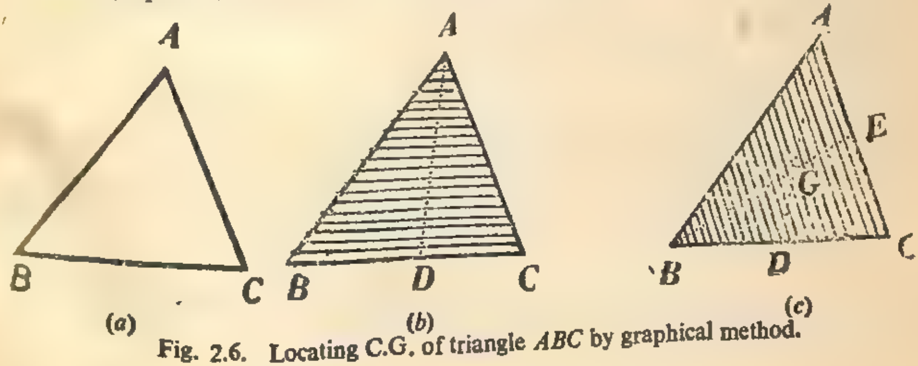


Fig. 2.6. Locating C.G. of triangle ABC by graphical method.

The C.G. of each strip lies half way along it. Hence the C.G. of the triangle lies on the line AD where D is the mid-point of BC.

(2) Now draw a similar set of lines parallel to AC as shown in Fig. 2.6(c). The C.G. of the triangle lies on BE where $AE=EC$. Thus the C.G. is at the point where AD and BE meet.

This method may also be followed for any other shape of a plane sheet provided the edges of the sheet are straight. The sheet is divided into triangles and quadrilaterals with the help of a pencil and scale and finally the C.G. position may be located by the above procedure and logic.

§2.06. Pupil's Activity No. 1(*d*)

C.G. Location by Calculation. The centre of gravity of regular thin sheets may also be determined merely by calculations, without doing any experiment. The underlying principle is that a body balances if supported on the tip of a pin at its C.G. One specimen calculation is discussed below.

Problem. A small disc of radius $R/2$ is cut out from a large disc of radius R as shown in Fig. 2.7(*a*). Find the position of the C.G. of the remaining portion of the large disc.

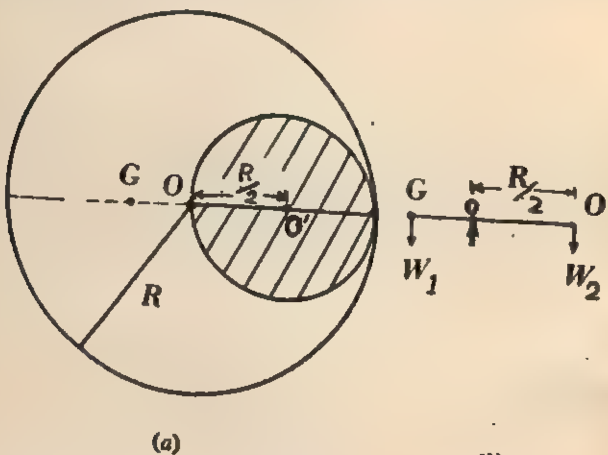


Fig. 2.7.

Calculation. Let the mass per unit area of the disc be m. By symmetry the C.G. of the disc (deprived of the small disc portion) must lie on the line OO' where O and O' are the centres of the large and small discs respectively.

Logic. Suppose the C.G. of the remaining large disc is at G on the line $O'O$ produced. Also suppose that the complete large disc system which balances at O, is replaced by a lever GOO' with its fulcrum at O and the forces acting at O' and G are the

weight W_2 of the smaller disc and the weight W_1 of the remaining large disc respectively as shown in Fig. 2.7(*b*).

Mass of the complete large disc $=\pi R^2$ m.

Mass of the small cut out disc $=\pi(R/2)^2$ m.

$=\frac{1}{4}\pi R^2$ m.

$\therefore$ Mass of the remaining large disc $=\pi R^2 \text{ m}-\frac{1}{4}\pi R^2$ m.

$=\frac{3}{4}\pi R^2$ m.

$\therefore$ Weight of the remaining large disc

$$W_1=\tfrac{3}{4}\pi R^2 \text{ mg.} \qquad ...(1)$$

and Weight of the small disc

$$W_2=\tfrac{1}{4}\pi R^2 \text{ mg.} \qquad ...(2)$$

Thus for the lever of Fig. 2.7(*b*).

Since anti-clockwise moment=clockwise moment.

$$\therefore \quad W_1 \,.\, OG=W_2 \,.\, \frac{R}{2}$$

$$\frac{3}{4}\,\pi R^2 \text{ mg. } OG=\frac{1}{4}\,\pi R^2 \text{ mg. } \frac{R}{2}$$

from equations (1) and (2)

$$\therefore \quad OG=\frac{\frac{1}{4}\pi R^2 \text{ mg. } R/2}{\frac{3}{4}\pi R^2 \text{ mg.}}=\frac{R}{6} \qquad ...(3)$$

Therefore the C.G. of the remaining large disc is at G which is at a distance $R/6$ from the centre of the large disc on the line OO'.

The logic of the above calculation may be applied to other cases of this type. The C.G. in such cases may also be determined by the experimental methods discussed above.

§2.07. Suggested Pupil's Activity

Students may try to locate the C.G. of a laboratory stool or an iron tripod or even a chair by the plumb line method. More skill and ingenuity are required to conduct this experiment in comparison with the simple cases of a lamina. Skill and ingenuity will be required in suspending the object in such a way that the plumb line positions can be located by the lengths of thin threads fixed with plasticine or quickfix.

§2.08. Types of Equilibrium

We have already discussed in §2.03 with the help of Fig. 2.2(*a*) and (*b*) that a body will be in equilibrium when (*i*) the resultant force acting on it is zero and (*ii*) the resultant moment of the forces acting on it is zero.

These two conditions of equilibrium for a body may be satisfied for different positions of it. But for some of these positions the

equilibrium of the body may be more **stable** than the other. According to the degree of stability of the equilibrium, there are three cases : **Stable, Unstable** and **Neutral** equilibrium. To understand this aspect of equilibrium let us consider the following demonstration experiment.

§2.09. Demonstration Experiment No. 4

Aim. To demonstrate the three types of equilibrium of rest of a body, *i.e.*, (*i*) **Stable**, (*ii*) **Unstable** and (*iii*) **Neutral** equilibrium.

Apparatus. A wooden or metallic cone, a cylinder (metallic or wooden), a glass or steel bead, a watch glass, a plane surface like drawing board and spirit level.

Procedure. (1) Level the drawing board with the help of the spirit level.

(2) Place the cone, and the cylinder on the drawing board as shown in Fig. 2.8 (a_1) and Fig. 2.8 (b_1) respectively. Also place the bead on the concave surface of the watch glass as shown in Fig. 2.8 (c_1).

(3) Displace, slightly, the cone, the cylinder and the bead one by one from their above positions. Let their displaced positions be shown by Figs. 2.8 (a_2), (b_2) and (C_2) respectively. Now release them. You will observe that all the three come back to their original positions. Therefore the **Equilibrium** represented by Figs. 2.8 (a_1), (b_1) and (c_1) is **Stable.**

(4) Now try to balance the cone with its apex on the drawing board as shown in Fig. 2.8 (a_3). You will observe that the cone does not balance in this position and falls on the drawing board. Thus the **Equilibrium** of the cone in this position is **Unstable.** Similarly the equilibrium of the cylinder and the bead as shown in Fig. 2.8 (b_3) and (c_3) is **Unstable.**

(5) Next put all the three bodies on the board in the positions as shown in Fig. 2.8 (a_5), (b_5), (c_4). Now roll them one by one and then release them. What do you observe ? The cone, the cylinder and the bead all the three remain in their new positions. Hence the **Equilibrium** is **Neutral**, *i.e.*, the bodies remain in whatever positions they are kept.

Explanation. According to the requisites of equilibrium of rest of a body, as we have discussed in the beginning of this article, the bodies in the positions of Figs. 2.8 (a_1), (a_3), (a_5), (b_1), (b_3), (b_5), (c_1), (b_3), (c_4) are in **Equilibrium.** It is so because in each of these cases no resultant force is acting on them and also there is no resultant moment acting (the C.G. in each case is vertically above the point of contact with the surface).

But we have seen above that the *degree of stability* of these equilibrium is different in these positions. In slightly displaced positions, a moment acts about the point of support or contact which may either bring the body back to its original position [as in Fig. 2.8 (a_2),

(b_2), (C_3)] or may turn the body *farther* away from its original position [as in Fig. 2.8 (a_4), (b_4), (c_3)]. In all the cases represented [Fig. 2.8

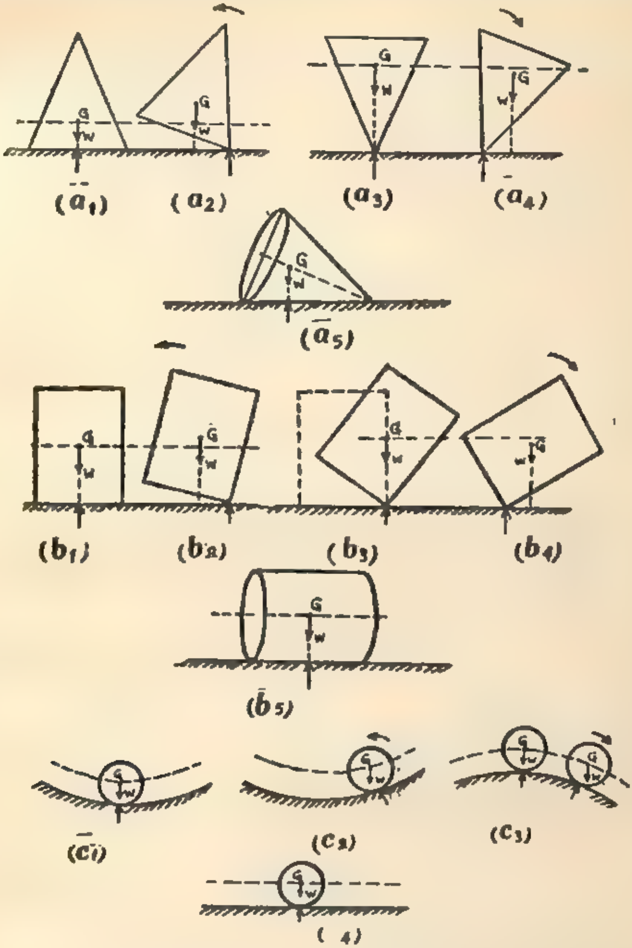


Fig. 2.8. Demonstration of Types of Equilibrium.

(a_5), (b_5), (c_4)] *no moment* acts on the bodies in the displaced positions, since the C.G. is always vertically above the point of support or contact.

It may also be noticed that the C.G. is raised in the disturbed positions of the bodies as shown in Fig. 2.8 (a_2), (b_2), (c_2). It is lowered in the disturbed positions as indicated in Fig. 2.8 (a_4), (b_4), (c_3). The C.G. is unchanged in the vertical direction for the disturbed positions of the bodies as shown in Fig. 2.8 (a_5), (b_5), (c_4).

Thus from the above observations and the explanations we conclude that the equilibrium of rest, is of three types as defined below :

Stable Equilibrium. A body is said to be in stable equilibrium if disturbed slightly and then released, it returns to its original position. In the disturbed position, the C.G. is raised and a moment acts on the body about the point of support or contact, which helps in bringing the body back to its original position.

Unstable Equilibrium. A body is said to be in unstable equilibrium if disturbed slightly and then released, it moves *farther* away from its original position. In the disturbed position, the C.G. is lowered and a moment acts on the body about the point of support or contact, which rotates the body farther from the original position.

Neutral Equilibrium. A body is said to be in neutral equilibrium if disturbed slightly and then released, it stays in its new position. In the disturbed position neither the C.G. is raised nor any moment acts on the body.

A careful inspection of Fig. 2.8 (a_2), (b_2) reveals that the equilibrium remains stable so long as the vertical line through the C.G. falls within the base. It may be concluded that the stability of equilibrium of a body is increased by

(1) **Increasing the Base Area,** and

(2) **Lowering the Centre of Gravity.**

§2·10. Examples of Equilibrium from Daily Life

(*i*) **Self-Erecting Toys.** These toys are designed so that they always stand erect. These toys have a curved (semi-hemispherical) base whose C.G. is below its centre of curvature. When the toy is tilted its C.G. is raised and also the point of contact with the support shifts. As a result a restoring moment acts on the toy about the point of contact which brings it back to the original position as shown in Fig. 2.9.

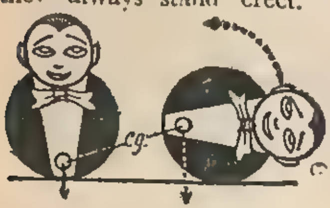


Fig. 2.9. Self-Erecting Toy.

(*ii*) **Indian *Lota* and *Patili*.** Indian *Lota* and *Patili* used in kitchen are designed such that they have lower C.G. positions. Thus

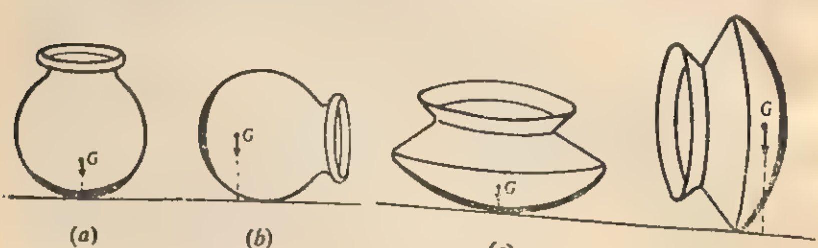


Fig. 2.10. Indian Lota.

Indian Patili.

they are made heavy bottom. When they are tilted they easily come back to their original positions as shown in Fig. 2.10. It is interesting to note that a patili can be tilted through 90°, even then it remains in the stable equilibrium.

(*iii*) A human child walks with the help of his hands and feet and falls when he tries to stand. He has to practise to train himself in such a way, that the vertical line passing through his centre of gravity falls within his two feet. On the other hand a cow baby can easily run because the area below his feet is large as it stands on his four feet. Thus even in tilted position the vertical line through his C.G. is within its feet.

(*a*) Fig. 2.11. (*b*)

(*a*) Man carrying a pail of water, (*b*) A porter has to lean.

(*iv*) Observe carefully the following phenomena and explain them with reference to the stability of equilibrium.

(*a*) A double decker bus taking a turn.

(*b*) A tight rope walker with a long pole or umbrella in hand.

(*c*) A bullock cart loaded with hay.

(*v*) A man carrying a pail of water in one hand, leans to the other side as shown in Fig. 2.11.(*a*). A porter has to leans forward while carrying a load on his back as shown in Fig. 2·11 (*b*). Explain these phenomena.

QUESTIONS

1. Complete the following with suitable word or words.

(*a*) The point where the whole weight of a body acts is called its......

(*b*) A body is said to be in equilibrium of rest when the resultant......and the net..... on it are......

(*c*) A body is said to be in equilibrium when its acceleration is.......

(*d*) The stability of a body is increased by......its centre of gravity.

(*e*) The C.G. of a body is neither raised nor lowered in the case of...... equilibrium.

2. Complete the following statements with suitable words selected from those given in the brackets :—

(*a*) Positions of centre of gravity and centre of mass of a body are....... [same, different]

(*b*) For stable equilibrium, the base of the body should be as......as possible. [small, large]

(*c*) When a body in unstable equilibrium is disturbed, its C.G. is....... [unchanged, raised, lowered]

(*d*) A body topples over when the vertical line through its C.G. falls...... its base. [outside, within]

(*e*) A cart carrying one quintal of iron is upset......than a cart full of one quintal of loose cotton. [more easily, less easily]

3. Several answers have been given for each of the following statements. Select the correct answer.

(*a*) A man while carrying a load on his back, leans......

(*i*) forward ; (*ii*) backward ; (*iii*) does not lean.

(*b*) A person carrying a bucket full of water in his right hand.

(*i*) leans towards his left hand, (*ii*) leans towards his right hand (*iii*) does not lean.

(*c*) Lead or mercury is used in the lower part of a hydrometer to

(*i*) raise its C.G. (*ii*) lower its C.G.

(*d*) Standing passengers are not allowed in the upper deck of a double decker bus because....

(*i*) it is inconvenient for the conductor to move about.

(*ii*) the heads of the passengers may collide with the roof.

(*iii*) the C.G. of the bus is raised and may topple the bus at curves.

4. Separate the correct statements out of the following :—

(*a*) The higher the C.G. the more stable a body is.

(*b*) A body cannot be in stable equilibrium if its C.G is lying outside the body itself.

(*c*) A body may be in stable equilibrium even if its C.G. is lying outside the body itself.

(*d*) Trucks, cars, boats are made heavy bottoms to keep them in stable equilibrium.

5. Why are the passengers in a boat asked to sit down ?

6. Why are the motorists advised not to put too heavy luggage on the roof-racks ?

7. Why does an old man use a stick for his support while walking ?

8. Why does a child keep his legs as far apart as he can while learning how to walk ?

9. Why are the legs of a chair or table generally inclined outward ?

3

Couple

§3.01. Points to Remember

(1) **Parallel Like Forces.** It is always possible to find the resultant of parallel and like forces (*i.e.* the forces which act along the same direction parallel to each other) acting on a body. Thus such forces can be represented by a **Single** force.

(2) **Parallel Unlike Forces.** In the case of parallel unlike forces acting along the same line (*i.e.* forces acting in the opposite directions) also it is possible to find their resultant so that they may be represented by a **Single** force.

(3) But in the case of parallel unlike forces of equal magnitudes which do not act along the same line, it is not possible to reduce them to a single force. Under the action of such a force a body will only rotate. In general, any system of forces which tends to cause rotation only, is called a **Couple.** A specific definition of a couple is given below.

(4) **Couple.** A couple is a pair of equal and opposite parallel forces which do not act along the same line.

(5) **Moment of a Couple.** It is the product of either force constituting the couple and the perpendicular distance between them.

(6) **Properties of a Couple.** (*a*) The effect of a couple is to produce only rotational motion in the body.

(*b*) A couple may be balanced (or its rotating effect may be cancelled) only by another couple of equal and opposite moment applied either in the same plane or in a parallel plane.

(*c*) The moment of a couple is independent of the position of the point about which the body rotates.

(*d*) The effect of a couple is unaltered by shifting it to another position in the same plane or in a parallel plane.

The above properties of a couple may be demonstrated by the following experime' ,

§3.02. Demonstration Experiment No. 4.

Aim. To demonstrate the properties of a couple.

Apparatus. A rod, four pulleys, weights and four hangers, strings, a fixed support like a stand or hook fixed in a ceiling and a protractor.

Procedure. (1) Hang the rod AB vertically by the string attached at A, the other end of the string being attached to a fixed support C as shown in Fig. 3·1.

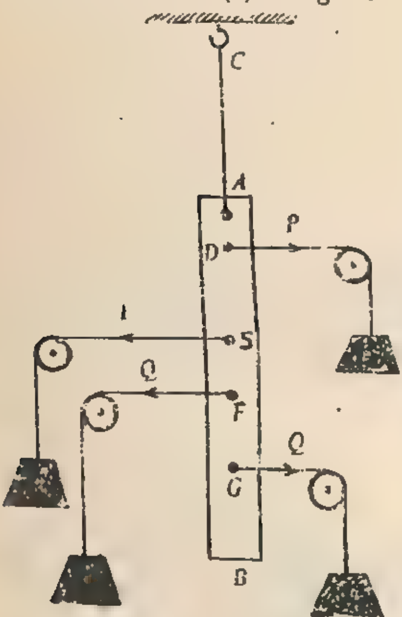


Fig. 3.1. Couples due to forces PP and QQ are clockwise and anti-clockwise directions respectively.

(2) Apply two equal, opposite and parallel forces P, P at the positions D and E, by means of the strings, two pulleys, and weights. Also apply another pair of forces Q, Q at the positions F and G by similar means. The pair of forces P, P and Q, Q constitute two couples trying to rotate the rod AB in opposite directions. The forces P, P and Q, Q should be made horizontal.

(3) Now adjust the values of the weights such that the rod AB remains vertical. Under this condition it will be found that the following equation is satisfied :

$$P.\,DE = Q.\,FG$$

$$i.e. \left[\begin{array}{l}\text{Moment of the couple due}\\ \text{to forces } PP \text{ (clockwise)}\end{array}\right] = \left[\begin{array}{l}\text{Moment of the couple due to}\\ \text{forces } QQ \text{ (Anti-clockwise)}\end{array}\right]$$

(4) Now remove one of the couples, (say QQ), and then try to balance the couple due to PP by applying a single force with your one finger on the rod AB. You will observe that the rod though shifts in the side direction but it still continues rotating. So it is not possible to balance it. Thus we conclude from above that *a couple can be balanced only by another couple of the same moment.* Also *a couple cannot be balanced by a single force.*

(5) Repeat steps (2) and (3) by inclining the parallel forces P, P at some angle to the horizonal and inclining the parallel forces Q, Q to a different angle, but arranging in such a way that the rod AB is again vertical. After calculations it will be found that in this case also the following relation is satisfied :

$$P.\left\{\begin{array}{l}\text{perpendicular distance}\\ \text{between the lines of action}\\ \text{of the forces } PP\end{array}\right\} = Q.\left\{\begin{array}{l}\text{perpendicular distance}\\ \text{between the lines of action}\\ \text{of the forces } QQ.\end{array}\right\}$$

§3.03. Examples of couple from Daily Life

(*i*) *Use of water tap.* To open or to close a water tap we apply a couple. The two forces, to constitute the couple, are applied, with thumb and fore finger as shown in Fig. 3.2.

(*ii*) To remove or to tighten the cap of vessels like inkpot, we apply a couple with our fingers.

(*iii*) A house-wife applies couple to the stem of the churner when she wishes to churn curd.

Fig. 3.2. To open or close a tap.

Fig. 3 3. Couple is applied to steeirng wheel.

(*iv*) A couple is applied by the hands of a driver to his motor car steering to give a turn to it as shown in Fig. 3.3.

(*v*) A cyclist, usually, applies a couple to the handle to turn it with his hands.

QUESTIONS

1. Complete the following statements with suitable words selecting from those given in brackets :—

(*a*) Two equal, parallel and opposite forces acting along different lines of action on a rigid body constitute a...... [single force, moment, couple]

(*b*) A couple......balanced by a single force. [can be, cannot be]

(*c*) The moment of a couple is......about different points in its plane. [the same, different]

(*d*) A couple......be balanced by another couple of the same moment acting in a parallel plane. [can, cannot]

(*e*) A force......a definite point of application, whilst a couple....... [has, has not]

(*f*) Moment of a force......on the point about which the body rotates and the moment of a couple......upon a similar point. [depends, does not depend]

2. Explain why it is easier to open the cap of a pen with the help of two fingers than with one finger.

4

Banking of Curves

4.01. Points to Remember

(1) **Uniform Circular Motion.** The motion of a body moving with a constant speed on the circumference of a circle is called *uniform circular* motion.

(2) A body in a uniform circular motion has constant speed but its velocity changes with time, because the direction of its motion changes continuously. The body, therefore, has an acceleration and this acceleration is directed towards the centre of rotation and is called the **Centripetal Acceleration.** It is given by the following relation.

$$\boxed{\text{Centripetal Acceleration } a=\frac{v^2}{r}}$$

where v is the linear speed of the body and r is the radius of the circular path. The *centripetal force* which acts on the moving body towards the centre of the path is given by

$$\boxed{F=m.\frac{v^2}{r}}$$

where m is mass of the body. The centripetal force given by this relation is necessary for holding a body in uniform circular motion.

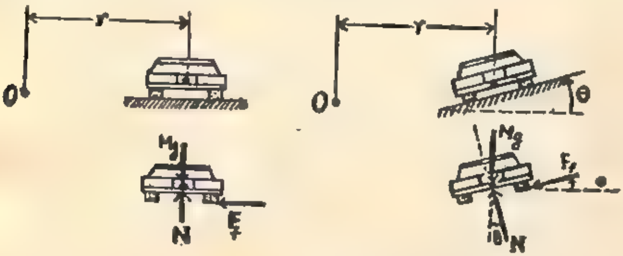
(3) According to Newton's third law of motion another force which is equal in magnitude and opposite in direction to the centripetal force comes into play. This force is known **centrifugal** force.

4.02. Banking of Curves

Whenever a car moves on the curved portion of a road, it requires a centripetal force. If the centripetal force is missing or is

insufficient, the car may slip away from the centre. The slipping of car is known as **skidding**.

Ordinarily this centripetal force is supplied by the frictional force F_f between the road and tyre of the wheel as indicated in Fig. 4.1 (*a*). But, in the case of a sharp curve and high speed of the car, the frictional force may be insufficient to supply the necessary centripetal force. Therefore, this centripetal force is supplied by raising the bed towards the outer edge of the road. This process is called the **Banking** of the road. Thus, the slope of the road bed is towards the centre O of the curve as shown in Fig. 4.1 (*b*).



(*a*) (*b*)

Fig. 4.1. A moving car on a curved road requires a centripetal force. Car moving on the curve of (*a*) plane (*b*) banked road.

Let us understand how this inclination or **Banking** of the road-bed at curves helps in providing the centripetal force.

Suppose a car of mass m moves with linear speed v along a circular curve of radius r as shown in Fig. 4.1 (*a*). When the road itself is horizontal, neither mg nor N, the reaction, has a horizontal component. In this case only the frictional force F_f is available to provide centripetal force. Thus

$$F_f = m.\frac{v^2}{r} \qquad \ldots(1)$$

According to this equation, as v becomes larger, the frictional force F_f must increase. If the limiting friction μN is exceeded, the car skids *i.e.* tends to continue on a curve of larger radius r than that of the road itself. Here μ is the coefficient of the friction.

If the roadway is slightly banked at an angle θ, as shown in Fig. 4.1 (*b*), both N and F_f have horizontal components directed towards the centre O. This implies that less frictional force is required. Let us analyse the problem algebraically :

Since the net force on the car in the vertical direction is zero, we get [from Fig. 4·1 (*b*)].

$$N \cos\theta - F_f \sin\theta - mg = O \qquad \ldots(2)$$

For the horizontal motion we have

$$N \sin\theta + F_f \cos\theta = m\frac{v^2}{r} \qquad \ldots(3)$$

By eliminating N from equations (2) and (3) we get (the steps for elimination are left to the reader)

$$\frac{F_f}{\cos\theta}=\frac{mv^2}{r}-m.g.\tan\theta \qquad \ldots(4)$$

Now the question is that how steeply should a road be banked ? To obtain the optimum condition, let us consider the worst possible situation when the frictional force F_f is absent. In such a case equation (4) reduces to

$$\boxed{\tan\theta=\frac{v^2}{rg}} \qquad \ldots(5)$$

In equation (5) r and g are constant for a given curve and therefore the **Angle of Banking** θ depends only on the speed v, being larger for larger speeds. For the cars of different speeds to negotiate with a curve, the banking angle is graduated. The banking angle gradually becomes steeper towards the outside edge. Cars moving at higher speeds keep towards the outer edge and those with smaller speeds keep towards the inner side.

When the speed of a car is more than the limit prescribed by equation (5), the frictional forces would have to be relied upon to prevent the car from skidding *up* the bank. Similarly if a cautious driver negotiates a curve at a speed less than the design velocity (again given by eqn. 5) the frictional forces again would have to be relied upon to prevent the car from skidding *down* the banked roadways.

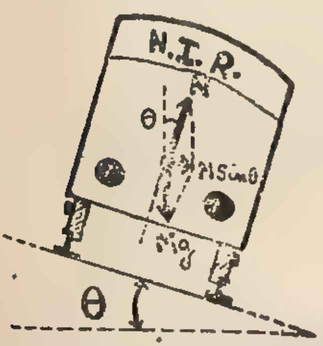


Fig. 4·2. A train negotiating a banked lines of a turn.

Similarly trains also negotiate with the curved railway lines due to banking of the lines. At the curves or the bends of the lines, the outer rail is placed a little higher than the inner one as indicated in Fig. 4·2. The train moves on banked lines with its floor inclined to the horizontal.

§4.03. Demonstration Experiment No. 5.

Aim. To demonstrate the effect of banking of curves.

Apparatus. A toy train with its curved lines, a toy bus which runs on its curved track, screw-driver, a few small strips of wood etc.

Procedure. (*i*) Wind the spring of the train fully by rotating its key tightly and let it run on its lines. (See Fig. 4·3). In case the train does not skid outwards, make the changes as below.

(*ii*) Dismantle the lines from its board with the help of screw driver. Bend them further at the curves so that if the step (*i*) is repeated the toy train falls outside, while moving on the rails.

(*iii*) Now, for this set curvature of the lines, make another suitable alteration by keeping the outer rail slightly higher than the inner one. The rails are now banked at the curve.

(*iv*) Repeat step (*i*) on the banked curve. You will note that the toy train does not go off the track.

(*v*) Make similar experiment with the toy car by inclining the surface of its track with the help of small strips of wood.

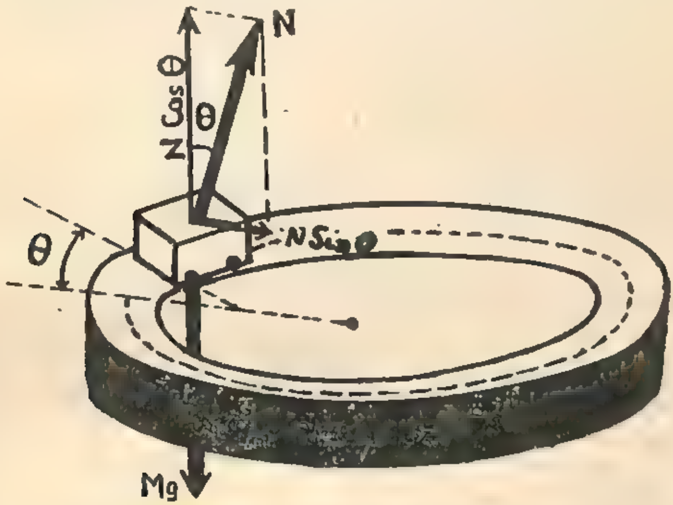


Fig. 4·3. A toy train moving on a circular "Banked" rails.

Conclusion. After banking the lines or the roads on curves a speedy train or a car can run without skidding.

QUESTIONS

1. Fill up the blanks in the following statements with suitable word or words :—

(*a*) A body in uniform circular motion moves with......speed but with a variable......

(*b*) If the earth stops rotating, the weight of bodies......

(*c*) When a cyclist takes a turn, he leans......

(*d*) Centripetal force is directed......the centre.

(*e*) Centrifugal force is directed......the centre.

2. Select the correct answers from the following statements :—

(*a*) Formula for centripetal force is

(*i*) $\frac{mv}{r^2}$, (*ii*) $\frac{mr}{v^2}$, (*iii*) $\frac{mv}{r}$, (*iv*) $\frac{mv^2}{r}$.

(*b*) A body is held in circular motion due to

(*i*) gravitational force (*ii*) centrifugal force (*iii*) centripetal force.

(*c*) A cyclist moving round a circular track at a constant speed has

(*i*) a constant linear velocity (*ii*) a constant acceleration (*iii*) an acceleration of constant magnitude.

(*d*) Banking of curved tracks is essential for speedy

(*i*) cars, (*ii*) motorcylist, (*iii*) trains, (*iv*) Rickshawala, (*v*) cyclist.

(*e*) A highly banked curved road is very suitable for

(*i*) a speedy car, (*ii*) slow moving car, (*iii*) a camel cart loaded with hay and moving slowly.

(*f*) An astronaut orbiting round the earth feels

(*i*) weightless. (*ii*) heavy weight, (*iii*) no change in weight,

(*g*) The curved tracks are banked to provide the necessary

(*i*) centrifugal force, (*ii*) centripetal force, (*iii*) mechanical advantage,

(*iv*) drainage of water due to heavy rains.

(*h*) The angle of banking depends upon.

(*i*) the weight of the moving car.

(*ii*) the speed of the car.

(*iii*) the radius of the curved track.

(*iv*) the width of the road bed.

(*i*) The angle of banking θ given by the relation $\tan\theta=\frac{v^2}{r.g}$

(*i*) takes into account the frictional forces.

(*ii*) does not take into account the frictional forces.

(*j*) A car moving with a speed higher than that given by $\tan\theta=\frac{v^2}{r.g}$, negotiates the curve safely......

(*i*) by chance, (*ii*) due to the frictional forces between the road and the wheel tyres, (*iii*) on account of his accurate driving.

(*k*) Banking of the curves is graduated

(*i*) because of the imperfectness of construction of the road.

(*ii*) to accommodate the cars of wide range of speeds.

5

Sound

§5.01. Points to Remember

(1) **Sound** is produced by vibratory motion of material particles. Sound requires a material medium for its propagation and it cannot travel in vacuum.

(2) Sound travels in the form of **waves**. These waves may be either **Longitudinal** or **Transverse** as discussed below.

(3) **Longitudinal Waves.** These are the waves in which the particles of the medium in which the wave travels, vibrate along the same line along which the wave propagates as shown in Fig. 5.1.

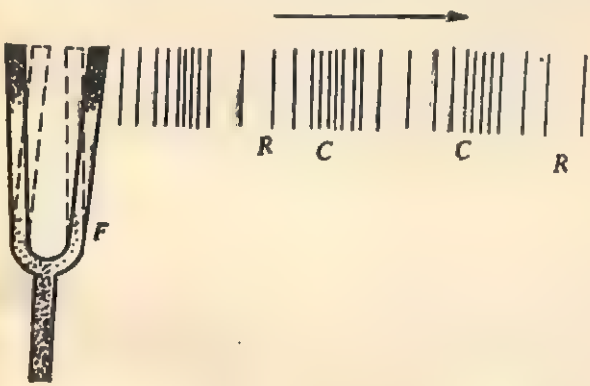


Fig. 5.1. Compressions (*C*) and Rarefactions (*R*) produced by a vibrating tuning fork F.

As the prong of the tuning fork vibrates, it presses the air particles in front of it, which in turn press the particles next to them and pressure is passed on to the successive layers of the medium. In this process **compressions** *C* and **rarefactions** *R* are formed as shown in Fig. 5.1. Sound always propagates in the form of **longitudinal waves** in gases and in some liquids. In solids, it may travel as longitudinal waves or as transverse waves.

(4) **Transverse Waves.** These are the waves in which the particles of the medium in which the wave propagates, vibrate about a line which is perpendicular to the direction of propagation of the wave. Sound travels in the form of transverse waves in strings.

(5) **Frequency.** The number of vibrations made in one second by the vibrating body is called its frequency. The unit of frequency is Hertz, usually written as H_z. It is defined as one cycle (or vibration) per second.

(6) **Time Period.** The time taken by a particle or body to complete one vibration is called its *time period.* If n and T are the frequency and the time period of a vibrating body respectively then it is clear from the above definition that

$$n=\frac{1}{T} \qquad ...(1)$$

(7) **Wave Length.** (Reference Fig. 5.1).

It is the distance covered by one compression pulse C and one rarefaction pluse R together, *i.e.*, the distance through which the *disturbance* travels in the time equal to the **time period.** Thus the velocity v of the wave is given by

$$v=\frac{\lambda}{T}$$

where λ is the wavelength of the wave. Substituting the value of T from equation (1) in this equation, we get

$$v=n\lambda \qquad ...(2)$$

(8) **Velocity.** The velocity of sound is proportional to $\sqrt{\frac{\text{pressure}}{\text{density}}}$. Pressure and density refer to the medium in which sound is travelling. Since at a constant temperature the ratio (Pressure/density) is constant for a gas and hence *the velocity of sound is independent of pressure.* The effects of other atmospheric conditions on the velocity of sound are as under

(*i*) **Temperature Effect.** The velocity of sound increases with temperature.

(*ii*) **Humidity Effect.** Velocity of sound in humid air is more than in dry air.

Regarding the effect of the medium, the velocity of sound in water is about *four times more* than in air at the same temperature. Also sound travels much *faster* in solids than in gases. Sound, however, does not readily pass from one medium to another when the media differ greatly in density.

§5.02. Demonstration Experiment No. 6 (*a*)

Aim. To demonstrate with the help of a **Crova's Disc** how compressions and rarefactions travel in a **Longitudinal Wave.**

Apparatus. A square piece of stout paper or thin card-board, another strip of card-board, white paper, a scissors, arrangement to draw circles on the white paper with ink and a nail.

Procedure

(*a*) **Preparation of Crova's Disc.** Paste white paper on a square card-board and draw a small circle at the centre of the pasted paper. Mark equidistant points as 1, 2, 3,......, 8 on the circumference of this circle as shown in Fig. 5.2.

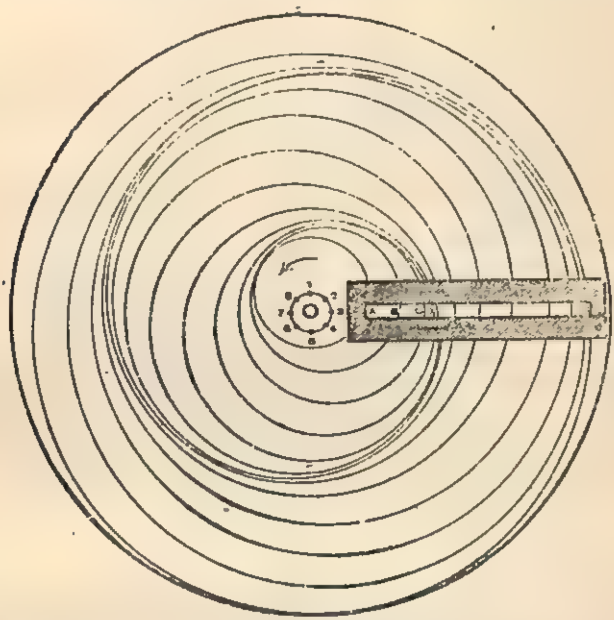


Fig. 5.2. Crova's Disc is used to demonstrate "Longitudinal Waves".

Now taking point 1 as centre, draw a circle of such a radius that it does not touch the previous circle. Then take point 2 as the centre and draw another circle of slightly larger radius. Using the remaining points 3, 4,......, 8 also successively as centres, a set of circles of progressively increasing radii are drawn. Now another set of circles is drawn again by taking the points 1, 2,......, 8 as centres as shown in Fig. 5.2. When the drawing of the circles is complete, cut the card-board in the form of a disc with a scissors. This disc is now put pinned with a nail at the centre of the smallest circle so that the disc may be rotated. Then a slit is cut out of a card-board strip and is placed in front of the disc as shown in Fig. 5.2.

(*b*) **Demonstration.** The disc is rotated by holding the slit stationary. The circular lines are seen through the slit moving towards the right hand side. It looks as if the circular lines are

coming closer and after combining, they are separating slowly from each other in succession. The idea of combining of the lines illustrate the **compression** and the separation illustrates the idea of **Rarefaction**. Also it is illustrated that the *compression*, the *rarefaction* and the *wave* move in the same direction *i.e.* towards right hand side in this case. Each individual layer (*i.e.*, circular line) simply oscillates about a mean position. The particles of the medium oscillate along the direction of the wave travel, hence, such a wave is named as *longitudinal wave*.

The idea of longitudinal waves may also be demonstrated by the following experiements.

Demonstration Experiment 6 (*b*).

To demonstrate the longitudinal wave motion with the help of a helical spring.

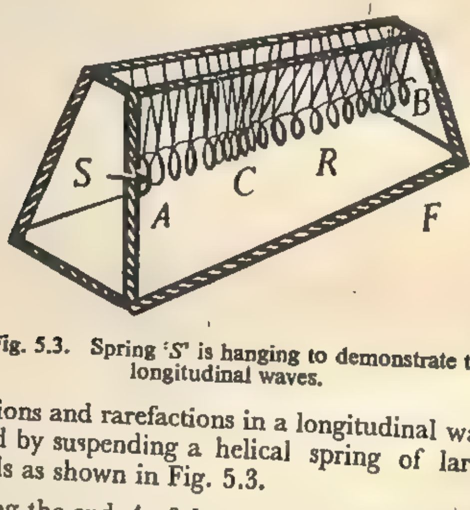


Fig. 5.3. Spring '*S*' is hanging to demonstrate the longitudinal waves.

Compressions and rarefactions in a longitudinal wave can also be demonstrated by suspending a helical spring of large length by means of threads as shown in Fig. 5.3.

On pushing the end *A* of the spring suddenly forward, the end part becomes compressed. This part will try to regain its position and in doing so, it will compress the part of the spring in front of it. In this manner compression travels to the other end *B* of the spring. Thus, if one end of the spring be alternately pushed and pulled in a periodic manner, longitudinal waves of **compression** and **rarefaction** will be seen to travel. In fact each turn of the spring executes to and fro motion about its mean position along the direction of travel of these pulses of compressions and rarefactions. Thus *the spring layers do not move bodily as a whole.*

Conclusion. In a similar manner, sound waves propagate through air such that the particles of air only move about their mean position of rest along the direction of propagation of the wave and are not *bodily transferred* from one place to another.

Demonstration Experiment No. 6 (*c*)

Longitudinal waves or compression waves can also be easily and conveniently demonstrated by the method discussed below.

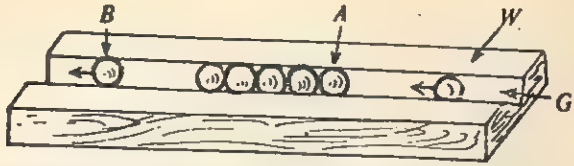


Fig. 5.4. Grooved plank and glass beads to demonstrate the mechanism of longitudinal wave propagation.

Arrange for a few glass beads and a wooden beam *W* having a groove *G* in which the beads can be put as shown in Fig. 5.4.

Put the beads touching one another, in the groove. Strike one bead against the end *A* of the row of the beads. You will observe that one bead flies apart at the other end *B*. The reason is that when the bead at *A* is struck, it is momentarily *compressed*. In recovering its shape it compresses the bead in front of it, and so on along the row. The last but one drives out the last bead in regaining its position. Thus *a wave of compression travels* down the row. If two beads in contact be driven against *A*, two will fly off at *B*. This is because now, two compression waves, one following the other, pass down the row.

N.B. (*i*) For the success of the experiement the beads should be **elastic** like steel balls or glass balls etc.

(*ii*) This apparatus can also be demonstrated for the conservation of *momentum and energy*.

§5.03. **Demonstration Expt. No. 7** (*a*)

Aim. To demonstrate the Transverse Wave Motion.

Apparatus. A "transverse wave model" which is very popular and commonly available from scientific dealers is shown in Fig. 5.5.

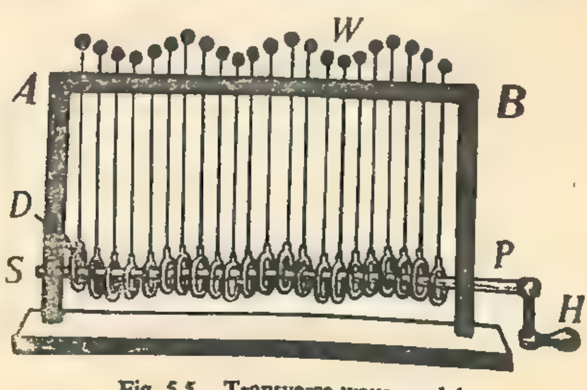


Fig. 5.5. Transverse wave model.

Construction. The "wave model" consists of a number of straight rods of equal length each of which carries a small bead at its top to represent a *particle* of the medium. These rods are placed at equal spacings parallel to one an other in a frame of a stand. Each rod rests on an eccentric disc D and passes through a hole provided for it, fitting loosely in a cross-piece AB held horizontally by the stand. All the eccentric discs have a common spindle (SP) which can be rotated by the handle (H).

Demonstration. Rotate the handle continuously and observe the motion of the balls at the tips of the rods. You will observe that *each ball undergoes a periodic up and down motion and a wave form travels from one end to the other* as shown in Fig. 5.5. *The direction of motion of each ball is perpendicular or transverse to the direction of propagation of the wave.* Hence, such a wave is known as a *transverse wave.*

Demonstration Expt. No 7 (*b*). Transverse wave motion can also be demonstrated by another model which may be prepared as discussed below.

Construction of the model :

Take a piece of thin card-board and draw lines parallel to one an other and equally spaced at a distance of about 2 mm as shown in Fig. 5.6 (*a*). Now alternate strips are cut with a sharp blade and then removed so that there are equally spaced parallel slits in the card-board. Paint this sheet completely with black colour. Draw

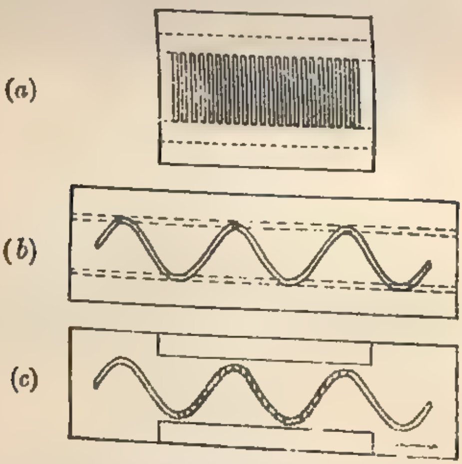


Fig 5.6. Transverse Wave Model prepared out of drawing paper strips.
(*a*) Slits cut in paper
(*b*) Wave cut in another paper
(*c*) Slit and wave papers combined to show wave motion.

two wave curves parallel to each other at a spacing of 2 mm. on another long card-board strip as shown in Fig. 5.6 (*b*). Cut out the space between these wave curves with the sharp blade. Now insert the wave curve card-board strip into the grooves of the *slit* card-board of Fig. 5.6 (*a*) as shown in Fig. 5.6 (*c*).

Demonstration. Insert the wave strip in the slit strip. Facing the wave strip throw light from the back of the slit strip with the help of a mirror and then slide the wave strip along, you will observe clearly the forward motion of a wave associated with up and down *i.e., transverse* motion of illuminated spots. The transverse motion of the illuminated spots corresponds to the transverse vibration of a string in which a sound wave is passing along the length of the string as in the case of a sonometer or Iktara, about which we shall discuss later in this chapter.

Demonstration No. 7 (*c*)

Transverse wave motion can be demonstrated by the well-known "Ripple Tank Apparatus" commonly available from scientific dealers.

Demonstration No. 7 (*d*)

Transverse wave motion can also be demonstrated with the help of "clay-balls".

Preparation. Eight or ten clay balls are prepared. Care should be taken to fix a thread in the balls while these are wet. When the balls become dry, suspend them with a rigid support *S* as shown in

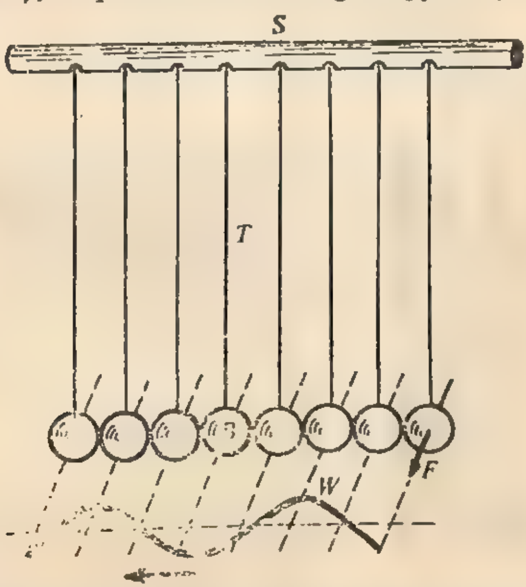


Fig. 5.7. Transverse wave travels along the curve from the right to the left when the end ball is displaced in the direction *F*.

Fig. 5.7 such that the centres of all the balls lie along the same horizontal line and also the balls touch each other.

Demonstration. Displace slightly the ball at the extreme right end in a direction *F* perpendicular to the line joining the centres of all the balls and then release it. You will observe that the displaced ball while recovering its original rest position displaces the next ball. In this way this disturbance is conveyed in succession. Finally, it reaches the ball at the other end. Notice keenly that the balls are disturbed in a direction perpendicular to the direction of travel of the wave. The wave in this case travels from the right to the left along the line joining the centres of all the balls. Hence, this is transverse wave motion.

§5.04. Resonance

Resonance is said to occur whenever a body or a system is set into oscillations due to sound vibrations coming from some other source in such a way that the frequency of the forcing source equals the natural frequency of the body.

Demonstration Experiment No. 8

Aim. To demonstrate resonance of Air-Column closed at one end.

Apparatus. A glass tube of about 3 cm. internal diameter and open at both ends, a glass jar containing water in which the glass tube may be dipped as shown in Fig. 5.8, a stand, a half-metre scale, a tuning fork of frequency 512 *Hz* or 480 *Hz* and a rubber pad.

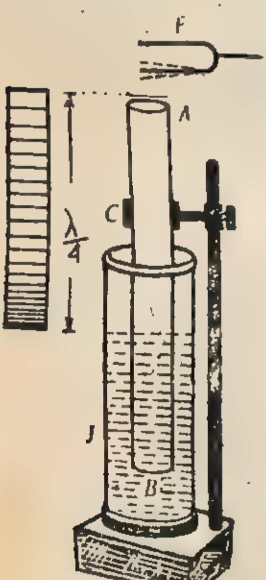


Fig. 5.8. Glass tube *AB* dipped in water contained in a glass jar *J*.

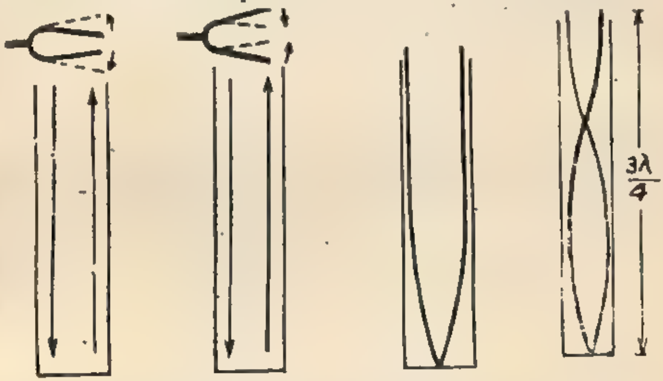
Procedure

(1) Set the apparatus as shown in Fig. 5.8.

(2) Strike the prong of the tuning fork on the rubber pad and place it above the open end of the tube (Fig. 5.8). You may hear some sound.

(3) Now repeat step (2) by increasing the length of air column between the water surface and the end *A* of the tube. You will observe that the loudness of the sound heard, increases near 17 cm. and finally, for a correct adjustment, it becomes maximum such that even a student sitting in the distant corner can easily listen to it. When the intensity of the sound heard becomes maximum, the air column is said to vibrate due to **"resonance"**.

Explanation. Let us understand with the help of Fig. 5.9 what happens when the air column **resonates.** Let us start considering the case when the lower prong of the tuning fork is in its extreme upper position. As the prong moves through half a *vibration,* it sends a pulse of *compression* down the tube which is reflected from the water surface in the tube and reaches back to the mouth of the tube as shown in Fig. 5.9 (*a*). Under the condition of resonance, the moment the *compression* reaches the top of the tube, the prong just reaches its lowest position and is ready for upward movement. When the prong starts moving upward from the lowest extreme position, it sends a *rarefaction* down the tube as shown in Fig. 5.9 (*b*). This rarefaction too is reflected by the water surface and returns back to the mouth of the tube in the time in which the prong completes one vibration. At this stage the fork has completed one complete *vibration* and has sent out one complete wave-length of sound wave. The



(*a*) (*b*) (*c*) (*d*)

Fig. 5.9. (*a*) Compression moves down and up.
(*b*) Rarefaction moves down and up.
(*c*) Representation of stationary waves for 1st position of resonance.
(*d*) Representation of stationary waves for 2nd position resonance (this drawing is to a different scale).

resonating length of the tube is travelled twice by the compression and twice by the rarefaction corresponding to one wave length. Therefore *the resonating length* (*l*) *of the tube is one quarter* ($\lambda/4$) *of a wave length.*

Similarly it may be argued that in the *second position* of resonance, the fork completes three vibrations in the time the sound travels four times (two times compression and two times rarefaction) the length of the tube. Therefore, in this case the length of the air column is equal to three quarters of a wave length as shown in Fig. 5.9 (*d*).

N.B. Owing to the difficulty of representing compression and rarefaction of a longitudinal wave diagrammatically it is customary to represent them by the method of transverse wave curve as shown in Fig. 5.9 (*c*) and (*d*).

End Correction. It was found theoretically by Lord Rayleigh that the reflection of compression and rarefaction of sound

waves at the open end of the tube should occur slightly above the end as shown in Fig. 5.9 (c). So a small correction has to be applied to the observed resonance length of the air column. This correction is called "end correction" and was found by Rayleigh to be 0·3 D where D is the internal diameter of the tube. Thus for the first resonance position

$$\lambda/4=(l_1+0{\cdot}3D)$$

and for the second position of resonance

$$3.\lambda/4=(l_2+0{\cdot}3D).$$

§5.05. Pupil's Experiment No. 4 (a).

Aim. To determine velocity of sound by using resonance column.

Method I

Apparatus. A tall glass cylinder nearly filled with water, a glass tube nearly 25 cm. in length and 3 cm. internal diameter, clamp and stand arrangement, a half metre scale, two tuning forks of frequencies 512 Hz and 480 Hz, a rubber pad, a thermometer (celsius), a plumb line, a long rubber tube to act like a siphon, a pinch cock, and a container.

Procedure. (i) Hold the glass tube AB by the clamp and stand arrangement, C, such that it dips in water contained in the jar J as shown in Fig. 5.10.

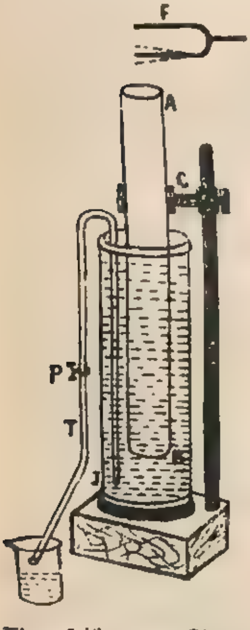


Fig. 5.10. Simple arrangement to determine the velocity of sound.

(ii) Make the tube AB vertical with the help of the plumb-line, by adjusting the clamp arrangement. Suspend the thermometer also by the side of the glass tube.

(iii) Dip the tube AB nearly to the bottom of the jar J such that only a small *air column* is left between the water surface inside the tube and its upper end. Dip the rubber tube T in the jar J up to the bottom and suck water from its other end and then pinch it with a pinch-cock P. Place this end of the rubber tube outside, below the bottom level of the jar J in such a way that water from this rubber tube may be drained out in another container, say, a beaker.

(iv) Hold the tuning fork by the stem and strike its prong *gently* on the rubber pad and place the vibrating tuning fork *just* above the upper (open) end of the tube AB so that its prongs vibrate in *vertical* plane.

(v) Now drain out water slowly from the jar J by opening the pinch-cock. You will listen increasing sound coming due to the vibration of the air column. By draining out water, the length of the air column in the tube AB is increased.

(*vi*) Fill up the jar J again with water and repeat step (*v*) at least four times to get the exact position of water level for which the intensity of the sound is maximum. Measure the length between the water level at this position and the upper end of the tube AB. Let this *resonance* length be l_1.

(*vii*) Repeat step (*iii*), (*iv*) and (*v*) with the second tuning fork also and tabulate the observations as detailed below.

(*viii*) Measure the internal diameter of the glass tube A with the help of the *upper* jaws of the vernier callipers and tabulate this observation also.

(*ix*) Record the room temperature in the beginning and at the end of the experiment with the help of the thermometer.

Theory. We have discussed in demonstration experiment No. 8 that for the first resonance position,

$$\lambda=4(l_1+0{\cdot}3D)$$

where λ is the wave-length of the wave, l_1 is the length of the *resonating* air column and D is the internal diameter of the glass tube.

Also $$V=n\lambda$$

where V is the velocity of the sound waves in air at room temperature and n is the frequency, therefore, we get

$$\boxed{V=4n\,(l_1+0{\cdot}3D)}$$

knowing n l_1 and D, the velocity of sound in air at room temperature may be calculated with the help of this formula.

Observations

1. Frequency of the first tuning fork $=n_1=480$ *Hz.*
2. Frequency of the second tuning fork $=n_2=512$ *Hz.*
3. Room temperature (*i*) in the beginning $=t_1=\ldots\ldots{}^\circ C$
   (*ii*) at the end $=t_2=\ldots\ldots{}^\circ C$
4. *For internal diameter of the glass tube,*
   (*i*) Zero error in the vernier callipers $=\ldots\ldots$cm.
   (*ii*) Least count of the vernier callipers $=\ldots\ldots$cm.
   (*iii*) Internal diameter of the tube in one direction $=D_1=\ldots\ldots$cm.
   (*iv*) Internal diameter in the perpendicular direction $=D_2=\ldots\ldots$cm.

5. For the resonating length l_1

Frequency of the tuning fork	*No. of observations*	*Length of the vibrating air column in cm.*	*Mean length l_1*
$n_1=480$ *Hz.*	1.	...	$l_1=$...cm.
	2.	...	
	3.	...	
	4.	...	
$n_2=512$ *Hz.*	1.	...	$l_2=$...cm.
	2.	...	
	3.	...	
	4.	...	

Calculations

Mean room temperature $=\frac{t_1+t_2}{2}=t°C.$

Mean diameter of the glass tube$=\frac{D_1+D_2}{2}=D$ cm.

Velocity calculation :

(*i*) Calculate V_1 by substituting $n_1=480$ *Hz*, $l=l_1$ and D in the formula $V=4n\,(l+0{\cdot}3D)$.

(*ii*) Also calculate V_2 by substituting $n=512$ *Hz*, $l=l_2$ and D in the above formula.

$\therefore$ mean velocity $V=\frac{V_1+V_2}{2}$ at room temperature $t°C$.

Result. Velocity of sound in air at ...°*C* is determined as...... metres/sec.

Precautions

(1) The glass tube should be set vertical by a plumb line.

(2) The pinch cock should be tested before use, so that water does not leak in the rubber tube (siphon tube) when the pinch-cock is closed.

(3) While setting the tuning fork into vibration by striking it on the rubber pad, there should be no metallic noise.

(4) The vibrating tuning fork should be held by its stem so that the vibrations of the prongs are not *damped*.

(5) When the vibrating tuning fork is placed above the mouth of the tube, the plane passing through the prongs of the fork should be *vertical*, and should not touch the edge of the glass tube.

(6) Water from the jar should be drained *slowly* with the help of the rubber tube acting as a siphon.

(7) Position of the exact resonance should be determined carefully. Therefore, the place of the experiment should be free from other noise and disturbances.

Method No. 2. Velocity of sound in air at room temperature can also be determined by the use of a conventional "resonance tube apparatus" which is commonly available from scientific instrument dealers.

Construction. The "resonance tube apparatus" consists of a 100 cm. long glass tube AB of about 2·5 cm. internal diameter fixed

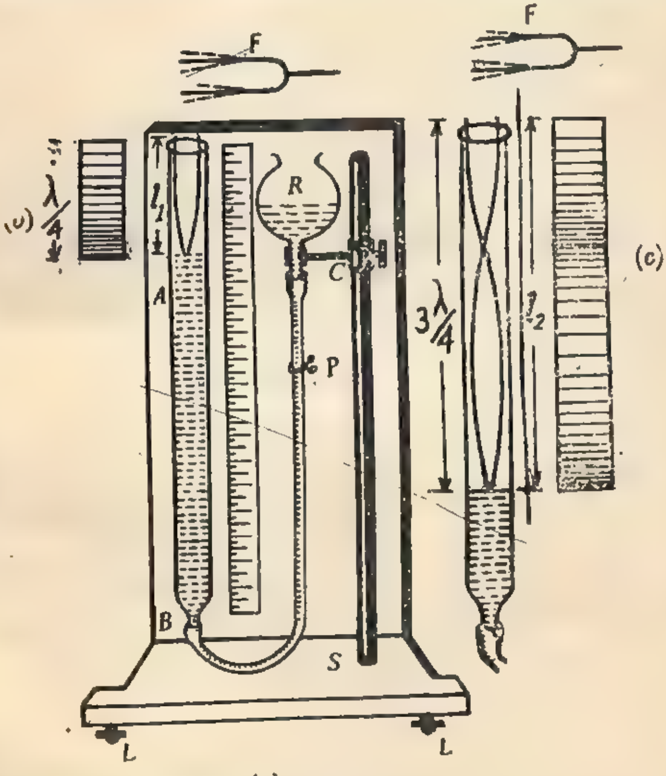


Fig. 5.11.

(a) Resonance tube apparatus.
(b) Position of first resonance.
(c) Position of second resonance.

on a vertical board along the side of a metre-scale marked in millimetres. The zero of the scale coincides with the upper end of the tube as shown in Fig. 5.11 (*a*). The lower end of the galss tube is drawn out and is connected to a reservoir *R* of water with the help of a rubber tube. A pinch-cock is attached with the rubber tube. The water level in the resonance tube *AB* can be adjusted by manipulating the adjustable screw attached with the reservoir clamp *C*. For fine adjustments of the water level in the tube *AB*, the pinch-cock *P* is used. The tube *AB* can be made vertical with the help of the levelling screws *L* provided at the heavy base of the frame.

Other Accessories

Two tuning forks of frequency 480 *Hz* and 512 *Hz*, a thermometer (celsius), a rubber pad, a beaker, a pinch-cock, a plumb line and a set-square.

Theory. Essentially, the resonance tube apparatus works on the principle which we have discussed in the theory of the previous experiment No. 8.

If l_1 and l_2 are the lengths of the air columns for the first and the second positions of resonance respectively, we get

$$l_1+x=\lambda/4 \qquad ...(1)$$

and

$$l_2+x=3.\frac{\lambda}{4} \qquad ...(2)$$

where x is the "end correction" and λ is the wave length of the sound wave.

Subtracting equation (1) from equation (2), we get

$$l_2-l_1=\frac{\lambda}{2}$$

or

$$\lambda=2(l_2-l_1) \qquad ...(3)$$

But

$$V=n\lambda \qquad ...(4)$$

where V and n are the velocity and frequency of the sound wave respectively, therefore, from (3) and (4) we get

$$\boxed{V=2n\ (l_2-l_1)} \qquad ...(5)$$

Thus we see that the expression (5) for the velocity of sound wave is free from the "end correction" term.

Procedure. (*i*) Set the resonance tube *AB vertical* with the help of the plumb-line and the levelling screws *L* at the base of the apparatus. Fill the reservoir *R* and some portion of the resonance tube with

water. Suspend the thermometer by the side of the resonance tube to note the room temperature.

(*ii*) Release the pinch-cock P and adjust the level of water in the resonance tube near the end A by adjusting the position of the reservoir R, and then, after closing the pinch-cock, lower down the position of the reservoir R.

(*iii*) Strike the tuning fork F *gently* on the rubber pad and place it just above the upper end A of the resonance tube so that the prongs of the vibrating tuning fork are in vertical plane. Now open the pinch-cock P and let the water level in the resonance tube fall slowly. At some position of the water level, you will listen sound of increasing loudness.

(*iv*) Repeat steps (*ii*) and (*iii*) to get the exact position of water level in the resonance tube for which the sound is of maximum intensity. Note the position of the level with the help of the set-square on the scale. Note the length l_1 of the resonance column as shown in Fig 5.11 (*b*). This position corresponds to the *resonance position.* Confirm the resonance position by taking *four* readings, two when the level of water is *falling* and the other two when the water level is *rising*. Note down these lengths l_1 of the air column.

(*v*) Lower the position of water level so that it is increased about *three* times the length l_1. Repeat steps (*ii*), (*iii*) and (*iv*) to get the second position of resonance with this tuning fork. Note this length l_2 of air column as shown in Fig. 5.11 (*c*).

(*vi*) Now take the second tuning fork and repeat steps (*ii*), (*iii*), (*iv*) and (*v*).

(*vii*) Note the room temperature with the help of the thermometer.

Record the observations as detailed below :

Observations

(*a*) Frequency of the Ist tuning fork $=(n_1)=480$ *Hz.*

Frequency of the IInd tuning fork $=(n_2)=512$ *Hz.*

Room temperature in the beginning $(t_1)=...°C.$

Room temperature at the end $(t_2)=...°C.$

Position of upper end A of the resonance tube$=$...cm.

(*b*) Table for the resonant lengths.

Tuning fork		*Resonance position*	*No. of Observations*	*Position of water level at resonance (cm.)*			*Mean Length of air column (cm.)*
No.	*Frequency Hz*			*Falling*	*Rising*	*Mean*	
First	480	Ist	1.	...	...	...	
			2.	...	...	...	$l_1=...$
		IInd	1.	...	...	...	
			2.	...	...	...	$l_2=...$
Second	512	Ist	1.	...	...	...	
			2.	...	...	..	$l_1'=...$
		IInd	1.	...	...	...	
			2.	...	...	...	$l_2'=...$

Calculation. (*i*) Calculate V_1 by **substituting the** values of n_1, l_1 and l_2 in the formula $V_1=2n_1(l_2-l_1)$.

(*ii*) Similarly, calculate V_2 from **the observations,** n_2, l_1', and l_2' from the formula $V_2=2n_2(l_2'-l_1')$.

$$\therefore \text{Mean velocity}=\frac{V_1+V_2}{2}\ \text{cm./sec.}$$

(*iii*) Mean room temperature$=\dfrac{t_1+t_2}{2}=t$°C.

Result. The velocity of sound in air at...°C is...metres/sec.

Pupil's Experiment No. 4 (*b*)

To determine the velocity of sound at 0°C.

Method. Experiment similar to the above is performed to determine the velocity of sound in air at *room* temperature and then by making use of the following formula, the velocity at 0°C may be calculated.

$$V_0=V_t-0{\cdot}61\times t \text{ metres/sec.}$$

In this relation V_0 and V_t represent the velocity of sound at 0°C, and at t°C respectively.

§5.06. Sonometer and Iktara (*Vibration of strings*)

Vibration of strings. Let us stretch a piece of a metal wire or a rope about one metre in length between two hooks or nails P and Q suitably fixed as shown in Fig. 5.12. The wire or rope is fixed tightly. Pluck the wire in the middle and observe that it *vibrates as a whole* such that a loop is formed. The amplitude of vibration of the wire is *maximum* at the *centre* and *zero* at the fixed *ends*.

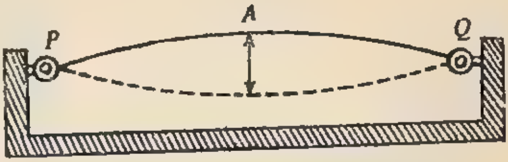


Fig. 5.12. Stretched string vibrating with fundamental mode.

The central *point A of the vibrating wire where the amplitude is maximum is called the Antinode and the end points P and Q at which the amplitude of vibration is minimum are called the nodes.* This is the simplest mode in which the wire vibrates as a whole in a single segment and is called its *fundamental mode.* The *frequency* of the sound wave emitted by the fundamental mode of vibration is called the **Fundamental tone,** which is the *lowest frequency* which the wire can produce.

However, there are many possible modes in which a stretched wire can vibrate and hence it can produce many frequencies, depending upon the mode of vibration. These possible frequencies are related by a definite rule and are *proportional to the* natural numbers *i.e.* are in the ratio of 1 : 2 : 3 : 4 etc. These frequencies are called **overtones.** The frequency of the **first overtone** is twice the *fundamental tone*, that of *second overtone* is thrice the **fundamental tone** and so on as represented in Fig. 5.13.

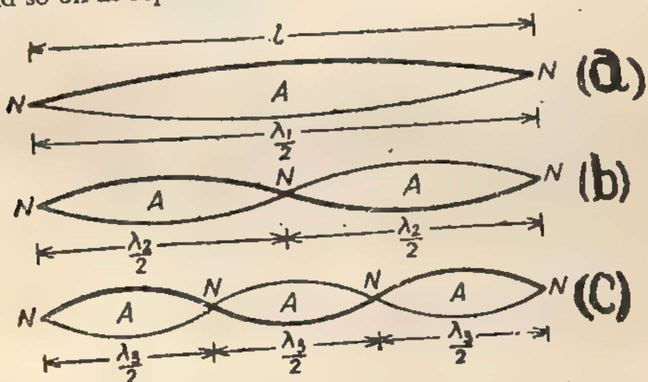


Fig. 5.13. Overtones produced in a vibrating string.

The **fundamental tone** of the stretched wire under tension at both the ends depends upon :

(*i*) The *length* of the wire between the fixed points.

(*ii*) The *tension* in the wire.

(*iii*) The *mass* per unit length of the wire.

If l, T and m are the *length*, the *tension* and the *mass* respectively, then the **fundamental tone** is given by

$$n_0=\frac{1}{2l}\sqrt{\frac{T}{m}}.$$

The frequency of first overtone [Fig. 5.12(*b*)] is given by,

$$n_1=2n_0=\frac{1}{l}\sqrt{\frac{T}{m}}.$$

Similarly, the frequency corresponding to any other tone may be calculated.

Sonometer. To study the vibrations produced by vibrating strings, an instrument called *sonometer* or a *monochord* is used.

Construction. It consists of a long sounding board or a box B with a peg G at one end and a pulley (P) at the other end as shown in Fig. 5.13. One end of a metal wire S is attached to the peg and the other end passes over the pulley. Weights on a hanger H are hung from the other end of the wire S to vary the tension in it. Two bridges W and W are provided for the purpose of altering the vibrating length of the wire. To understand the working of a sonometer let us conduct the following demonstration experiment.

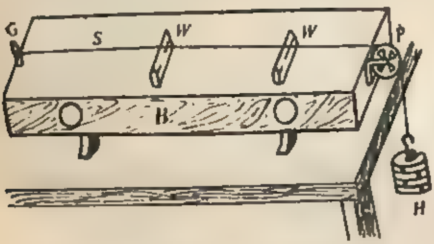


Fig. 5.13. Sonometer.

Demonstration Experiment No. 10

Aim. To demonstrate the formation of nodes and antinodes for the cases of various modes of vibration of a string with the help of a *sonometer*.

Apparatus. A sonometer or the arrangement shown in Fig. 5.14, hanger and weights, a bird's feather or a strip of thick paper, a piece of paper, a scissors and a bow.

Procedure. (*i*) Cut thin and small pieces of paper with the scissors and form V shaped *rider* out of these pieces. Touch the wire gently with the feather at its centre. Now bow the wire at a point mid-way between the centre and one of the bridges (W) keeping the bow nearly vertical. You will observe that now

the wire vibrates in *two segments* and thus the *first overtone* is produced.

(*ii*) Put the paper *riders* along the wire at equal spacing between the bridges. Now remove two riders from one side, and in their place put the feather and the bow as shown in Fig. 5.14. Touch the wire with feather at the position shown and bow the wire to set it into vibrations. You will observe that only the alternate riders jump off and the rest remain stationary on the string. These riders which remain stationary represent the positions of **Nodes** and those which flied off represent the positions of **Antinodes**.

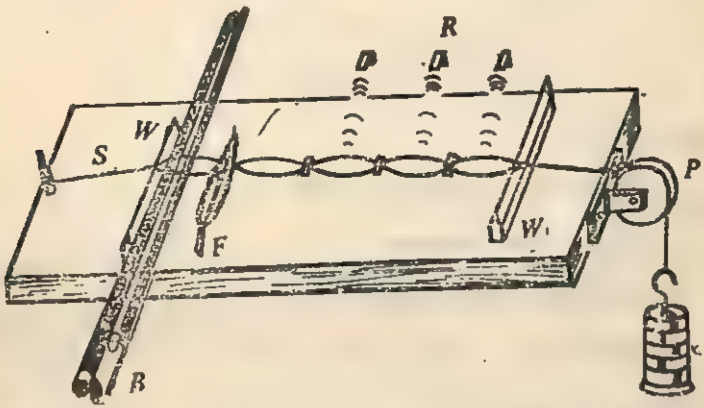


Fig. 5.14. Demonstration of Overtones (*B*—Bow ; *F*—Feather *R*—Paper Rider).

Thus a stretched string may be set into any mode of vibration.

Iktara or Monochord

It is a stringed musical instrument having a single string and hence the name monochord or Iktara. The meaning of Iktara is 'one wire'.

Construction and Working. It is an instrument in which one metallic string *S* is kept taut, as in sonometer, as shown in Fig. 5.15 (*a*). The string is set into vibrations with a bow *B* shown in Fig. 5.15 (*b*). *P* represents a sound box, the purpose of which is to increase the intensity of sound produced. One end of vibrating portion of the string is fixed at the wedge *V* and its other end is at the position where the player puts his or her finger. When the player bows the string near the wedge *V*, by keeping his or her finger at some position of the string, it is set into vibrations and thus the string produces *overtones* which is nothing but the "musical sound". By moving the position of the finger up the string, thus effectively shortening the string, musical sound of higher notes are produced. Cheap models of toy Iktara, which toy sellers sell in cities and villages, are very popular among children.

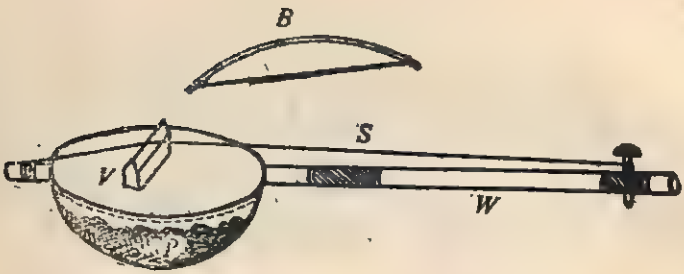


Fig. 5.15. (*a*) Iktara or monochord.
(*b*) Bow.

QUESTIONS

(*A*) Wave Motion

Pick up the correct alternative from the brackets and complete the following :—

(*a*) Sound......travel in vacuum. [can, cannot]

(*b*) Sound travels...... [in the form of wave, along a straight line]

(*c*) Sound travels in the form of......waves in gases. [transverse, longitudinal]

(*d*) Sound travels......in solids than in liquids. [slower, faster]

(*e*) Sound travels......in liquids than in gases. [faster, slower]

(*f*) Particles of the medium vibrate along the same line along which the wave propagates in the case of......waves. [transverse, longitudinal]

(*g*) Particles of the medium vibrate perpendicular to the line along which the wave propagates in the case of......waves. [transverse, longitudinal]

(*h*) To transfer sound energy from one place to another, the particles of the medium...... [move, vibrate]

(*i*) Material medium is......for the propagation of sound waves. [not necessary, necessary]

(*j*) Velocity of sound increases with the increase of......of the medium. [pressure, temperature, humidity]

(*k*) In the case of sound wave motion, all the particles of the medium get disturbed at ...... [the same time, different times]

(*l*) Sound waves travel......than light. [slower, faster]

(*m*) Ultrasonic waves have......greater than the......of sound waves. [frequencies, velocities]

(*n*) Supersonic waves have......greater than the......of sound waves. [frequencies, velocities]

(*o*) Velocity of a bullet fired from a gun is......the velocity of sound. [equal to, greater than, less than]

(*p*) Material particles......move faster than the velocity of sound. [can, cannot]

(*q*) Material particles......move faster than the velocity of light. [can, cannot]

(*r*) The quantity which does not change is......in the case when sound travels from one medium to another. [velocity, amplitude, frequency, wave length]

(*B*) Musical Sound

1. **Pick up the correct alternative from the brackets and complete the following:**

(*a*) ......to......vib./sec is the range of audibility for the human ear. [20 to 40,000 ; 20 to 20,000]

(*b*) The persistence of hearing for a normal human ear is not more than ......of a second. [1/10, 1/20]

2. Complete the following sentences with suitable words or phrases :—

(*a*) (*i*) ...... (*ii*) ...... (*iii*)......are the characteristics of a musical sound.

(*b*) Intensity or loudness depends on......

(*c*) Pitch of a musical note depends upon the......of the source of sound.

(*d*) Quality of a musical sound depends upon......

(*e*) The voice of a woman has a greater......than that of a man.

(*f*) The voice of lion is different from that of a mosquito because the two animals have different......

(*C*) Resonance Tube (Viva-voce)

(*a*) Justify the proverb : "An empty vessel makes much noise".

(*b*) Why does the resonant frequency of the air column rise when water is poured in a tall cylinder ?

(*c*) How will it affect the resonance position if some oil is used instead of water in Resonance Tube Apparatus ?

(*d*) How will it affect the resonance position if the resonance experiment is performed on a mountain ?

(*e*) How will it affect the resonance position if a heavy gas like CO_2 is filled in the resonance apparatus at atmospheric pressure ?

(*f*) What is end correction ?

(*g*) Why do we not take a narrow resonance tube to make the end correction negligible ?

(*h*) How will you test whether the rosonance apparatus is vertical ?

(*i*) What is the use of a pinch-cock generally attached to the rubber tubing ?

(*j*) How is the end correction eliminated ?

(*k*) Will the resonance position be changed if the diameter of the tube is changed ?

(*l*) Why do we use a long tube for resonance experiment ?

(*m*) While taking both the positions of resonance, will you choose a tuning fork of higher or lower frequency ?

(*n*) Why is the intensity of sound comparatively less in the second position than in the first position of resonance ?

6

Properties of Matter

§6.01. Points to Remember

(1) **Elasticity.** All material bodies when subjected to suitable forces, suffer a change either in **size** or in **shape** or in both and get *deformed*. When the deforming force is removed the body tends to come back to its original condition. This *property of a body by virtue of which it regains its original condition after the removal of the deforming force is called* **Elasticity.** Bodies which recover completely after the removal of deforming forces are called **perfectly elastic** and those which do not show any tendency to recover are called **perfectly plastic** bodies. In actual practice, we have no perfectly elastic or perfectly plastic bodies, the difference being that of a degree, a body may be more elastic or plastic when compared with another body.

(2) **Stress.** The deforming forces applied to a body give rise to forces of reaction inside it, tending to restore it back to its original condition. This restoring or *recovering force set up inside the body measured per unit area is called* **Stress.** It is equal in **magnitude** but opposite in **direction** to the applied deforming force per unit area provided the elastic limit is not exceeded.

Further, if the deforming force is trying to press the body, the stress is named **compressive stress** but if the deforming force be of a nature of pull or tension, the stress is called **tensile stress.** Since stress is force per unit area, its unit is the same as that of pressure. Thus it is measured in N/m^2.

(3) **Strain.** Due to the deforming force there is a change in the dimensions of the body. **Strain** *is defined as the ratio of change in length or volume to original length or volume.* Since it is a ratio, it has no units.

(4) Out of *stress* and *strain* which comes first ? As is clear from the definition of strain, unless strain *i.e.* deformation is produced there is no stress or no recovering tendency in a body. Hence *strain* is an *independent* quantity and *stress* is a quantity which depends upon the *strain.*

§6 02. Demonstration Experiment No. 12

Aim. To demonstrate the properties of elasticity, plasticity, malleability, ductility and brittleness of substances.

(*i*) **Elasticity.** Take a rubber string and measure its length with the help of a scale. Now stretch the string and then measure its length. You will find an increase in its length. Now release the rubber string and measure its length again. You will find that it regains its original length. This indicates that rubber is an elastic substance.

Conduct a similar experiment with a steel wire. You will not find any measurable (with the help of the scale) change in its length. However, if the length of the wire is very large, say 10 metres, then in the stretched position there will be some change observable. This indicates that the "*steel*" has stronger capacity to oppose the strain than rubber. Therefore, *steel is more elastic than rubber.*

(*ii*) **Plasticity.** Take *wet earth* and *plasticine* and roll them. Measure the lengths of these rolled wet earth and plasticine pieces. Now pull these pieces lengthwise and measure their lengths again. You will find that their lengths are permanently increased. Such *substances which do not recover their sizes and shapes after the removal of the deforming forces are termed as plastic substances.*

(*iii*) **Malleability.** Take a *silver* wire and hammer it. You will find that the wire is *flattened.* By such hammering, the substance can be made in the form of thin sheets. *This property of a substance by virtue of which it can be hammered into the sheets is called* **Malleability.**

Gold, lead etc. are examples of good malleable substances. Since solids become more malleable when hot, this makes the rolling of metals into sheets possible.

(*iv*) **Ductility.** Take an iron strip in which there are small holes of different sizes. Fix it on the table with two nails. Now insert one end of a **thick** silver wire in one of the holes of the strip and pull it with the help of a plier. You will observe that the silver wire is drawn into a thinner wire. *This property of a substance by virtue of which it can be drawn into fine wires* is called **Ductility.** Quartz and platinum are examples of ductile substances. Lead is malleable but not ductile because it cannot be drawn into fine wires. Ductility increases with temperature.

(*v*) **Brittleness.** Take a piece of *dry earth* or glass and hammer it. You will see that the *earth piece* or the glass piece is broken in smaller pieces. This property of a *substance by virtue of which it is broken into small pieces due to hammering etc. is called its brittleness.* Porcelain, china clay etc. are examples of *brittle* substances. Generally very hard solids are brittle. Brittle substances like cast iron support a large forces of *compressions,* they easily break if stretching (tensile) forces are applied. Where stretching or tensile forces are

involved, elastic materials such as steel are used. By *tempering*[1], when solids are hardened, their brittleness increases. Thus tempered steel, though very hard, is brittle. Molten glass beads when suddenly cooled by water are rendered so brittle that they can be crushed to fine powder at the mildest blow. Therefore, to reduce the brittleness of substances like glass, steel etc. annealing[2] process is adopted. Thus good quality glass tumbler which we use in daily life is made after cooling the glass for a longer time. Shock proof glasswares are manufactured these days by permitting molten glass to cool very slowly for many days.

QUESTIONS

1. Fill up the blanks with suitable word given in the brackets.

(*a*) Rubber is......elastic than iron. [more, less]

(*b*) The ratio of stress and strain, under the elastic limit for a helical spring of steel is equal to the.......
[Young's modulus of steel, modulus of elasticity of the spring]

(*c*) Hooke's Law states that under the elastic limit,.......
[stress λ strain- constant, stress ∝ strain, strain ∝ stress]

2. Why does a steel ball, dropped on a stone floor bounces higher than a stone ball ?

3. How does the elasticity of a substance depend upon temperature ?

4. Breads are rolled out of wet flour because it is.........
[elastic, malleable, plastic]

5. The crease of a terrycot shirt is longer lasting than that of cotton shirt because terrycot cloth is......than cotton cloth
[less elastic, more elastic]

6. Goldsmith is able to draw fine wires of silver because silver is......
[malleable, ductile, elastic, plastic]

7. Solids have definite shape due to...... [cohesion, adhesion]

---

1. Tempering is the process of *sudden cooling* of a hot substance by dipping it in a cold liquid.

2. Annealing is the process of *slow cooling* of a substance.

7

Model of Our Solar System

§7·01. Points to Remember

(1) **Stars.** If you look at the sky on a clean moonless night, you will observe a large number of shining objects or specks of light like jewels embedded into the interior surface of a vast hollow dome of the hemispherical shape. These shining objects are called **stars.** Owing to the vast distance from us, they appear as points. On account of changes in the density of layers of air, they appear to **Twinkle.** They are at rest relative to one-another. However, each star appears to rise from the east and to set in the west, describing a circle. The only exception is the **Pole-star** which appears to be stationary.

(2) **Planets.** If observed carefully, some shining objects in the sky appear to move among the 'fixed stars'. The ancients knew five such objects besides the sun and the moon. These objects are called the **Planets** (a planet means wanderer). Unlike a star, a planet does not twinkle, instead, it appears as a small disc. The five planets which can be observed with naked eye are **Mercury, Venus, Mars, Jupiter** and **Saturn.** Besides these, three more planets have been observed with the aid of telescopes. They are **Uranus, Neptune** and **Pluto.** Thus in all there are nine planets, including the earth, in the **Solar System.**

(3) **Asteroids.** These are minor planets revolving round the **Sun** in the belt between **Mars** and **Jupiter.** Some asteroids are as big as the city of New Delhi or New York and others are smaller in size. One of the popular asteroids is the **Eros.**

(4) **Meteors** and **Meteorites.** Besides asteroids, small pieces of matter like stones, are also revolving around the **Sun.** Sometimes, these bodies are able to enter the earth's atmosphere. Owing to their high velocity, a large amount of heat is produced in overcoming the frictional force of the air. The heat produced is so intense that these objects become incandescent, *i.e.*, they start emitting light and ultimately start burning. These **shooting** stars are called **Meteors.** They are frequently seen at the night time. Practically all the innumerable

meteors plunging into the earth's atmosphere are consumed up by the air atmosphere and as such are unable to land on earth. Occasionally, however, such an object may be too big to be consumed by the atmosphere and is thus able to land on earth. It is then called a **Meteorite.** A big crater in Arizona is believed to have been caused by the impact of a meteorite. Don't get terrified by this statement about the crater. The probability of a meteorite hitting the earth's surface is exceedingly remote and for this we should be highly obliged to the thick envelope of atmosphere protecting us.

(5) **Comets.** Sometimes a star with a long tail is also observed in the sky. It is the **Comet.** The appearance of a comet has been considered as the sign of ill-omen. However, it is a harmless object. Most of its part is in the gaseous state. The matter contained in it is so diffused that entire of it can be packed in a suit-case. It revolves round the sun along a highly eccentric elliptical **Orbit**. The head of the comet is always towards the **Sun** and its tail is always directed away from the **Sun**. In certain cases the tail is as long as 3 to 4 miles. The orbit of a well known comet *i.e.*, **Halley** is shown in Fig. 7.1.

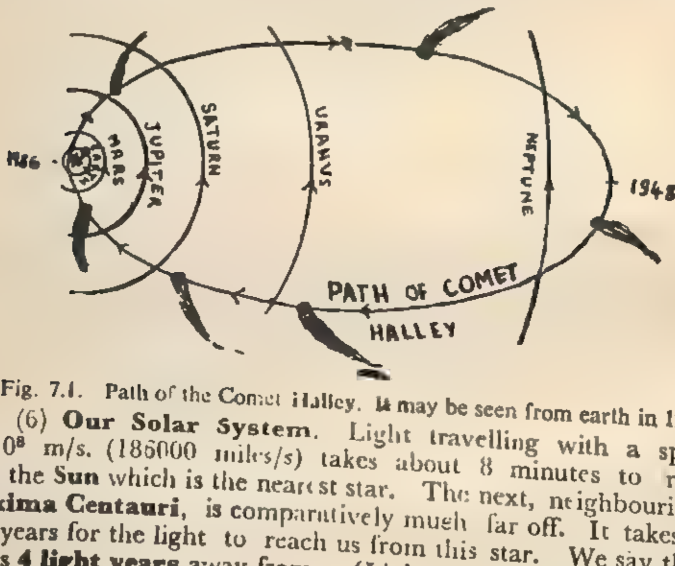


Fig. 7.1. Path of the Comet Halley. It may be seen from earth in 1986.

(6) **Our Solar System.** Light travelling with a speed of 3×10^8 m/s. (186000 miles/s) takes about 8 minutes to reach us from the **Sun** which is the nearest star. The next, neighbouring star, **Proxima Centauri**, is comparatively much far off. It takes nearly four years for the light to reach us from this star. We say that this star is **4 light years** away from us (Light year is the **distance** that light covers in one year).

The **Sun** is the central object of a huge system of nine planets and some objects like **Meteors, Asteroids** and **Comets.** This family of the **Sun** in called our **Solar System.** It is possible that there may be other planets also besides these nine and some astronomers are trying hard to look for them Each planet of the solar system revolves round the **Sun** in a defeiate path These paths are nearly circular but actually elliptical. Each path is called the **Orbit** of the planet. The

names of these planets are listed in Fig. 7.2. Planets vary in size considerably. The table I, listed below, gives the details regarding the size

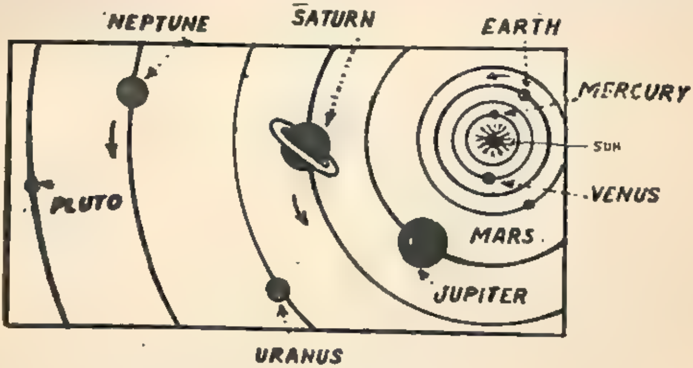


Fig. 7.2. Diagram of the Solar system.

of a planet and the average distance of its orbit from the **Sun**. **It is** clear from the table that **Mercury** is the smallest planet. Its diameter is about two-fifths of the diameter of the earth. **Jupiter** is the largest planet with a diameter of about 11 times that of earth. Orbit of **Mercury** is the nearest to the **Sun** whereas the outmost planet is **Pluto**. The earth on which we live, is a medium sized planet and is the third from the **Sun.**

Table I

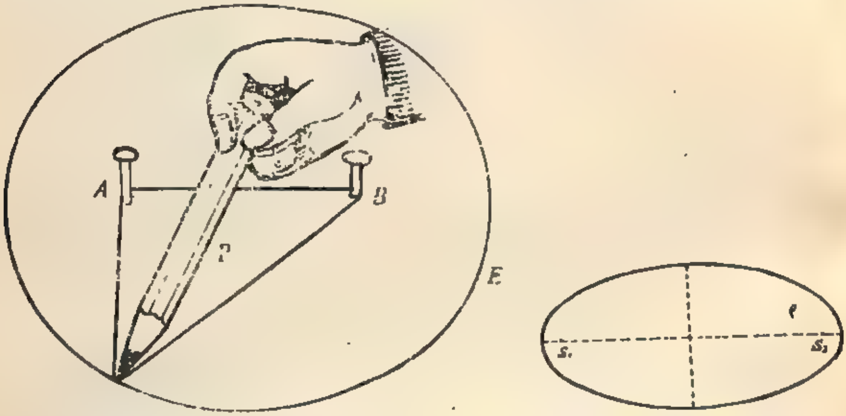
Size of planets and their distances from the **Sun** (or Radii of the orbits) of our solar system.

	Mercury	*Venus*	*Earth*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*	*Pluto*
Diameter (size) in km.	4,900	12,000	13,000	6,800	140,000	120,000	50,000	53,000	13,000
Radius of Orbit (in 10^6 km)	60	108	150	228	778	1,420	2,870	4,490	5,900

(7) **Ellipse.** In general, the orbit of a planet is elliptical and therefore, let us discuss how to draw an ellipse.

Fix two nails or drawing pins *A* and *B* into a sheet of paper on a drawing board. Place a loop of string loosely over the two pins. Now take a pencil with sharp point and make the string taut by the use of the pencil and then draw the ellipse as shown in Fig. 7.3(*a*). The points on which the two nails are fixed, correspond to the two *focii* of the *ellipse*. If the ellipse required is approaching the shape of a circle then the length of the string loop should be large and the distance between the two nails should be small [Fig.7.3(*a*)]. For an ellipse

of large eccentricity to be drawn, the length of the loop should be small and the distance between the two pins should be large as shown in Fig. 7.3(*b*). The elliptical orbits of planets are nearly circular but the orbit of a **Comet** is highly elliptical, differing very much from the shape of a circle as shown in Fig. 7.1. The maximum and the minimum diameters of earth's elliptical orbit are neatly in the ratio of 101 : 100.



(*a*) Nearly circular ellipse (*b*) Highly elliptical.

Fig. 7.3. Drawing an ellipse.

§7.02. Pupil's Experiment No. 1

Aim. (*a*) To prepare a model of the **Solar System** showing the **Sun** and **Planets** and (*b*) to discuss experimental difficulties in making the drawing to the scale.

Apparatus. A square wooden plank or a square hard board of size measuring 1·75 m., long iron or copper wire of about 1 mm. diameter, plastic or wooden beads to represent the planets (in the absence of the plastic beads, plasticine or modelling clay may be used to make beads of different sizes), arrangement to draw holes in the beads. The following table II gives the approximate relative sizes of the beads which represent the planets. This table also gives the relative diameter of the orbits to a **different scale**.

Table II

Sizes of planets and their orbits for the **Model.**

Planet	*Mercury*	*Venus*	*Earth*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*	*Pluto*
Diameter of planet in cm.	2/5	19/20	1	½	11	9	3¾	3½	½
Radius of Orbit in cm.	0·7	1 5	2·0	3·0	10·4	19·5	38·4	60·1	79·2

Theory. In preparing the model of our **Solar System** we are going to assume the following :

(*i*) The ellipticity of the **Orbits** of different planets is very small. In fact for the earth's orbit, the maximum and minimum diameters are nearly in the ratio of 101 : 100. Therefore, the **Orbits** in the model may be made **circular.**

(*ii*) The diameters of the planets and the diameters of the orbits are drawn to **different scales**. The scale for the orbit is much larger. The reason for choosing different scales is discussed in part (*b*) of the experiment.

(*iii*) The **planes of orbits** of different planets are inclined to one another. The **maximum** inclination is about 16°. With respect to the plane of "ecliptic" the maximum inclination of the orbital planes are 8° on either side. This inclination of 8°, being small, is neglected and hence the planes of all the orbits are considered to be the same as the plane of the "ecliptic" in the model.

Procedure. (1) Paint the wooden plank white.

(2) Draw nine concentric circles on the plank, with pencil, of radii as given in second row of table II.

(3) Drill holes in the plastic beads diametrically, size of the drilling bit being equal to the thickness of wire to be inserted in.

(4) Now bend the wire along different circles drawn and then cut their lengths. These bend wires will represent the **Orbits.** Insert the plastic beads representing the **Planets,** in their circular wires respectively. Finally two ends of the circular wire are joined together by twisting them.

(5) Now cut holes in the plank one on each circular **Orbit** in such a way that the size of the hole is equal to the size of the plastic bead on the orbit. Place the circular wires along with the beads on the plank by coinciding them with their corresponding orbits and fitting the beads into the holes drawn. The wires may be fixed on the plank with transparent adhesive tape or by any other suitable means.

(6) Paint the **Centre** of the orbits red to represent the **Sun**.

(7) Suitable mechanical arrangement may be provided to either hang the plank, with the model, on wall or display on a classroom table.

Limitation of the Model : The model designed will look like the one shown in Fig. 7.4. This model is not **accurate** because we have chosen different scales for the **Sizes** of the planets and the **Distances** of the planets from the **Sun**. In an accurate "Scaled

Model" every length should be proportional to the same scale. The reason for choosing two scales is discussed below.

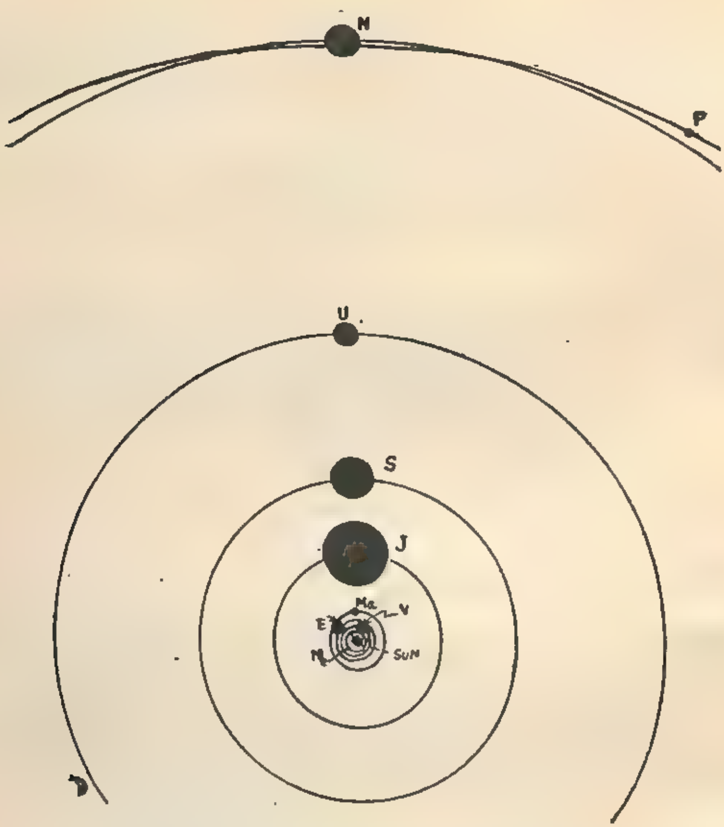


Fig. 7.4. Sachcmatic out line of our **Solar System**, showing relative sizes of **Orbits** and, to a different scale, the relative sizes of **Planets**. For the names of planets see Fig 7.2.

(b) Practical Difficulties in Making the Model to the Scale

(i) **Scaled Model.** Let us first understand the meaning of the term "Scaled Model". You must have seen a map on which a scale is written. It may state that 1 cm. represents 100 km. or so. It means that a distance of 1,000 km. will occupy a length of 10 cm. on this map. Thus the *lengths on a "Scaled Map or Model" are proportional to the* **Actual** *distances*. Let us now understand the difficulties in making a "Scaled Model" of the solar system.

(ii) **Difficulties.** (a) Look at table **I** which shows sizes of the **Orbits** and sizes of the planets. You will conclude that it is possible to make "Scaled Model" of **Planets** with proper attention to their relative **sizes** only. It is also possible to make "Scaled Model" of the

Orbits of planets with proper attention to only their **Distances** from the **Sun.**

But to follow both of these scales (*i.e.* the relative sizes of the **Planets** and their **Distances** from the **Sun)** at the **same scale** requires a very large space. It can be drawn only out of doors on some large area of land which is a difficult job. Thus it should be realized that the drawing used in this book or other text books for the solar system is not accurate "scale drawing". The following calculations will illustrate this point.

To draw the **scaled** model for the smallest planet Mercury having a diameter 4900 km. and moving in the orbit of radius 60,000,000 km., let us choose the **scale** such that the size of Mercury is 1 mm. (*i.e.* 4,900 km.=1 mm.). Then if the same *scale* is used to represent the radius of the orbit of Mercury, then the radius on the model comes out to be $\frac{60,000,000}{4900} \simeq 12 \times 10^3$ mm $\simeq 12$ metres.

Using the same **Scale** for the orbit of **Pluto**, which has the maximum radius of $5,900 \times 10^6$ km., the corresponding radius on the model comes out to be $\frac{5900 \times 10^6}{4900} \simeq 1{\cdot}2 \times 10^6$ mm. $\simeq 1{\cdot}2$ km. Students now can easily realise that such distances (1·2 km.) cannot be drawn on a paper of even largest size.

(*b*) Also it is impractical to include the size of the sun on the scale chosen for the size of the planets, because the sun is much larger than the largest planet, Jupiter.

QUESTIONS

1. Complete the following sentences by choosing suitable words from the brackets :—

(*i*) Light year is the unit of...... [time, distance]

(*ii*) One light year is the......by light in one...... [time taken, distance travelled, minute, year]

(*iii*) A planet may be said as a......heavenly object. [twinkling, wandering]

(*iv*) Moon is a....... [planet, star, satellite]

(*v*) In a scaled map it is......for the lengths of lines to be proportional to the actual distances. [not necessary, necessary]

(*vi*) One......draw the model of the solar system in a book by keeping only the distances of the planets from sun *to scale.* [cannot, can]

(*vii*) The orbit of earth is...... [highly elliptical, nearly circular]

(*viii*) Orbit of a comet is....... [nearly circular, highly elliptical]

(*ix*) A planet of our solar system is held in orbit due to the......force between the planet and..... [magnetic, gravitational, another planet, the sun]

8

Velocity and Acceleration

§8.01. Points to remember

(*i*) **Velocity.** The rate of change of position of a body in a particular direction with respect to time is called its velocity.

(*ii*) **Uniform velocity.** A body is said to move with a uniform velocity if it covers equal distances in a particular direction in equal intervals of time, however small the time interval may be.

(*iii*) **Variable velocity.** If a body covers unequal distances in equal intervals of time or the direction of motion changes, the body is said to move with *variable* velocity.

(*iv*) **Acceleration.** The rate of change of velocity of a body in motion is called its acceleration.

(*v*) **Uniform acceleration.** If the velocity of a body changes equally in equal intervals of time, however small these time intervals may be, it is said to move with *uniform acceleration.*

§8.02. Velocity (From "*distance-time*" graph).

Velocity at any instant may be determined from the "*distance-time*" graph. Let us consider the velocity calculations for uniform and variable velocities from 'distance-time" graphs.

(*i*) *Uniform velocity.* The distance-time graph for such a case is given in Fig. 8.1 (*a*) which is straight line. Take any point A on the graph and drop perpendicular AB on the time-axis. AB represents the distance moved by the body in time OB and therefore :

$$\text{Velocity} = \frac{\text{distane}}{\text{time}} = \frac{AB}{OB}.$$

$\frac{AB}{OB}$ is called the gradient or slope of the line OA. The velocity at any instance from the distance-time curve is given by the slope of the curve at that pt.

The velocity of any other point on the line OA is the same as given by the above calculation.

(ii) *Variable velocity.* Fig. 8.1(b) represents the "distance-time" graph of a body moving with variable velocity. In order to find velocity at any instant represented by point A, a tangent to the curve at this point A is drawn as discussed below.

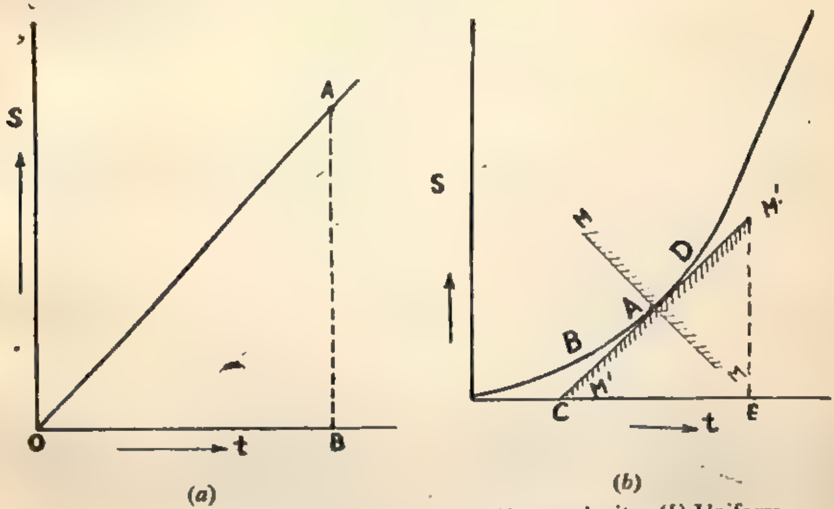


Fig. 8.1. Time-distance graph for (a) Uniform velocity (b) Uniform acceleration (variable velocity).

Take a strip of plane mirror and place it edge-wise such that its reflecting surface is over the point A in the position MM as shown in Fig. 8.1(b). See the image of the portion AB of the curve in the mirror and adjust its position by rotating it about the point A such that the image of the part AB coincides with the portion AD of the curve. This will happen when the mirror is **perpendicular** to the curve at the point A. Mark the straight line MAM on the paper with the help of a sharp pencil along the edge of the mirror. Now draw a line $M'AM'$ perpendicular to MAM at the point A with the help of the mirror or a protractor. This line $M'AM'$ is the **tangent** to the curve at the point A.

Now draw the perpendicular $M'E$ from the point M' on the time axis. From the triangle $CM'E$

$$\text{Velocity at } A = \text{slope at } A = \frac{M'E}{CE}.$$

It is clear from the graph that, since the inclination or the slope of different parts of the curve is different, the velocity at different points of time is different. Velocity at any point is given by the **slope** of the curve at that point and the slope may be obtained with the help of the *mirror strip* as discussed above.

8.03. Pupils' Experiment No. 2

Aim. To show that bodies can be in an accelerated motion and to verify the relation $v=u+ft$.

Note. This experiment can be conducted in different ways. Three such methods will be discussed here. It is hoped that at least one method will suit the laboratory facilities of all the schools.

Method 1. Gallileo's Inclined plane method.

Apparatus. A long and plane wooden plank about 4 to 5 metres length having '*V*' shaped straight groove cut on it from one end to the other along its length, a glass or steel or marble bead, a stop watch of 1/10″ accuracy, a metre scale and a plane mirror strip.

Procedure. (*i*) Incline the plane of the grooved plank with respect to the horizontal by raising the end *A* suitably and by holding the end *B* against two nails fixed in the table as shown in the Fig. 8.2.

(*ii*) Now release the glass bead from top end *A*. It may roll down the plank with a uniformly accelerated motion. Adjust the inclination in such a way that the time taken by the ball to roll down the entire length is large and yet the motion is accelerated, which is checked by the increasing velocity of the ball while it rolls down the plank.

(*iii*) Now take the observations by noting down the time taken by the bead to cover different distances from the end *A*. Each observation should be confirmed at least three times.

(*iv*) Tabulate the observations as below.

(*v*) Plot a graph of distance *vs.* time as shown in Fig. 8.1(*b*) and from it calculate the velocities at different instants of time as discussed below. Finally plot a velocity-time graph as shown in Fig. 8.3.

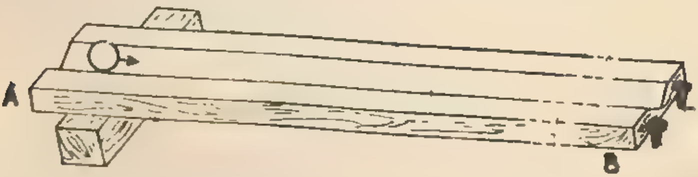


Fig. 8.2. Plank with V-shaped groove.

Observations

Least count of the stop watch =...Sec.

Table for Distance and Time

S.N.	*Distance S from end A (cm.)*	*No. of Obser.*	*Time taken (t) (sec.)*	*Mean time (t) (sec.)*	*Velocity V from (S–t) graph. (cm./sec.)*
1	10	1. 2. 3. 4.			
2	50	1. 2. 3. 4.			
3	100	1. 2. 3. 4.			
4	150	1. 2. 3. 4.			
... ...	... ...	... ...			

Calculations. (*i*) Draw trangents to different points on the curve of "distance-time" graph with the help of a mirror strip as

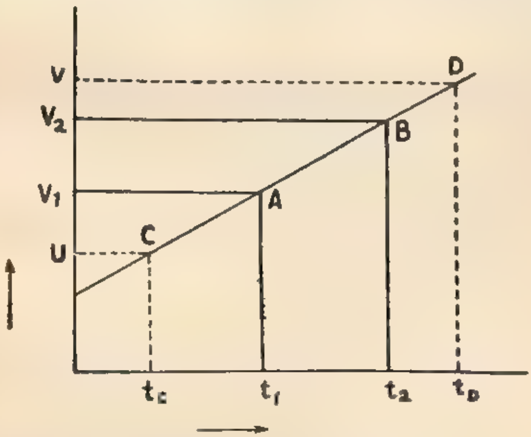


Fig. 8.3. Velocity-time graph from distance-time graph for an uniformly accelerated motion.

explained in §8.02 (*ii*) and determine the **slope** of the curve at various points. These **slopes** will give the velocities at different instants of time. Insert these velocities in the last column of the table.

(*ii*) Now draw a velocity-time graph with the quantities in the last two columns. This graph will be a straight line as shown in Fig. 8.3.

(*iii*) Take two points A and B on the velocity-time graph. Let v_1, t_1 and v_2, t_2 be the velocities and times for these points respectively.

Since acceleration f = Rate of change of velocity

$$= \frac{\text{change in velocity}}{\text{time taken for the change}}$$

or
$$f = \frac{v_2 - v_1}{t_2 - t_1} = \text{slope of the curve} \quad ...(1)$$

Hence the slope of the "velocity-time" graph is the **acceleration.**

(*iv*) Repeat the above calculation for f for other sets of points on the graph. It will be found that f is the same for all these points also. It means that acceleration is uniform. So we see that a *straight line velocity-time represents a uniformly accelerated motion.*

(*v*) Now take any two other points C and D on the graph of Fig. 8.3. Let the velocity at the point C be U and that at the point D be V. Note the time instants for these points as t_C and t_D. Let $t_D - t_C = t$. Now substitute the values of U, V, t and f from equation (1), in the following relation

$$V = U + f \cdot t \quad ...(2)$$

You will find that left hand side is equal to the right hand side (within the errors of experimental limit).

(*vi*) Calculate U, V and t for different pairs of the points like C and D. You will find that the relation $V = U + ft$ is satisfied in all the cases.

Result. (*i*) Since the bead covers successively increasing distances in *equal intervals* of time while rolling down the inclined plank, it is illustrated that bodies can be in accelerated motion.

(*ii*) The relation $V = U + ft$ is found to be true for uniformly accelerated motion.

Precautions. (*i*) The wooden plank should be plane.

(*ii*) 'V' shaped groove must have proper cutting.

(*iii*) The watch must be accurate one (1/10 sec).

(*iv*) The inclination must remain fixed for the entire sets of observations, otherwise the acceleration will not remain uniform.

(*v*) A sharp pencil should be used to trace the curve and also tangent to it.

Method No. 2. *To verify the relation* $v = u + ft \left(\text{or } f = \frac{v - u}{t} \right)$ by a trolley and ticker tape vibrator.

1. Apparatus. A ticker tape vibrator, long paper tape, a smooth and long inclined plane and a trolley.

Description of ticker tape vibrator. This instrument consists of a disc *D* of carbon paper which can rotate due to the moving tape *T* under it as shown in Fig. 8.4. There is an iron strip *S* just above the carbon disc which has a small hammer attached to it so that dots may be put on the tape when the strip vibrates. The strip vibrates when an altering current (of 50 Hz) is passed through the electromagnet coil *C*. The detailed construction of the *vibrator* is shown in the Fig. 8.4. *N*, *S* represents a permanent horse-shoe magnet.

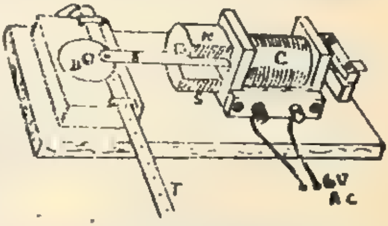


Fig. 8.4. Ticker-Tape-Vibrator.

Make your own ticker-tape vibrator. In case this instrument is not available from the market, you can make your own ticker-tape vibrator by modifying an electric bell as detailed below :

(*i*) Bring an electric bell of usual type as shown in Fig. 8.5.

(*ii*) Remove the Gong (lid) *G* and detach the hammer *S* but retain the soft iron armature **A**.

(*iii*) Extend the armature **A** by soldering to it a strip of metal **S** about 5 cm. long as shown in Fig. 8.6.

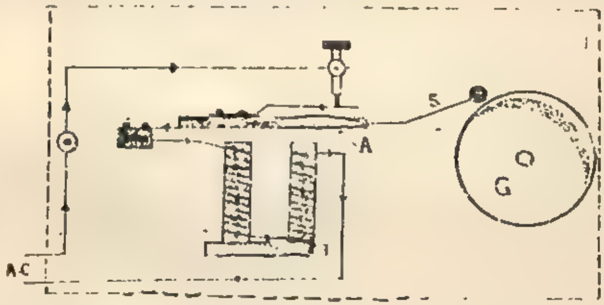


Fig. 8.5. Electric Bell.

(*iv*) Drill a hole at the vibrating end of the strip *S* to fit a small rounded head screw *H*. Fix the screw with the head *H* downwards to act as a marking hammer (Fig. 8.6).

(*v*) Fix this modified arrangement of the electric bell on a piece of wood which serves as a base as shown in Fig. 8.6.

(*vi*) Make a carbon disc *D*, about 3 cm. in diameter. Hold this disc loosely at the centre by a drawing pin on another wooden piece such that the disc rotates when a moving paper tape *T* slips under it. The rotation of the disc exposes new surface of the disc to the hammer *H*, as the tape passes under it.

(*vii*) This assembly of the carbon disc is fixed on the base plate as shown in Fig. 8.6.

(*viii*) If necessary, bend the strip S suitably so that the hammer does not press the tape too hard. In the case of hard pressing, the frequency of the vibrations may be irregular.

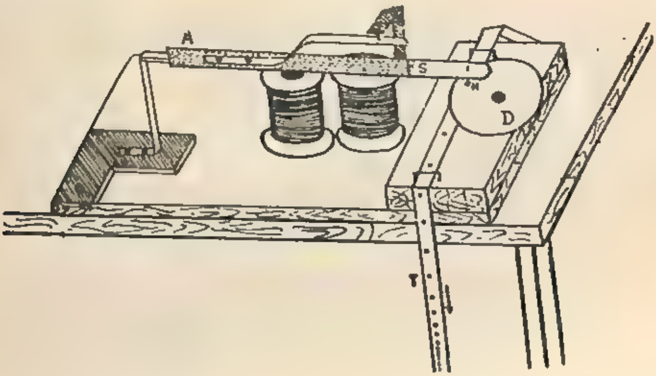


Fig. 8.6. Ticker-tape vibrator made from an electric bell.

(2) Procedure

(1) Tilt the runway with suitable packing pieces at one end such that the trolley moves on it with suitable acceleration.

(2) Attach the end of a long paper tape to the trolley.

(3) Fix the ticker-tape vibrator at the starting upper end of the runway such that the paper tape passes under the carbon disc.

(4) Now switch on the current to start vibrations of the ticker Allow the trolley to move down the runway. You will notice that *dots* on the paper-tape are marked. The spacing of the successive dots *increases* due to accelerated motion. However, the *time interval for two successive dots is the same* and it is governed by the constant frequency of the vibrator.

(5) Repeat step (4) many times with fresh tapes and for different inclinations of the runway and collect the dotted tape. For the calculations and interpretation of the result, adopt the following steps :

(3) Theory and Calculations

Take one of the dotted tapes and ignore first few dots as shown in Fig. 8.7. The distances x_1, x_2, x_3..., between the ten (10) successive dots are measured. The frequency of the vibrator is $50 H_z$. Thus the tape takes $1/50$ sec.$=0{\cdot}02$ sec., to cover the distance between two

successive dots. Therefore, the trolley takes $10\times\cdot02=0\cdot2$ sec. to travel each distance x_1, x_2, x_3 cm etc.

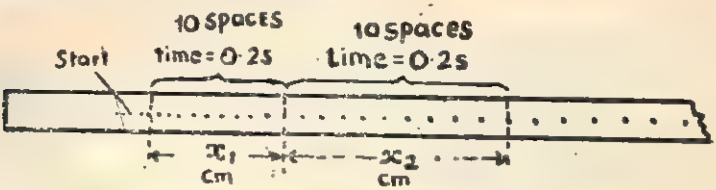


Fig. 8.7. Dots marked by a ticker-take vibrator on a paper tape.

Average velocity for the distance $x_1=\frac{x_1}{0\cdot2}$ cm/sec.

and Average velocity over the distance $x_2=\frac{x_2}{0\cdot2}$ cm/sec.

Hence the increase in velocity in 0·2 sec. $=\frac{x_2}{0\cdot2}-\frac{x_1}{0\cdot2}=\frac{x_2-x_1}{0\cdot2}$ sec.

Since, $$\text{acceleration}=\frac{\text{change in velocity}}{\text{time}}$$

$\therefore$ $$\text{acceleration } f=\frac{x_2-x_1}{(0\cdot2)^2}\text{ cm/sec}^2$$

If we take u and v as the corresponding initial and final velocities, we get

$$u=\frac{x_1}{0\cdot2} \quad \text{and} \quad v=\frac{x_2}{0\cdot2}$$

$\therefore$ $$f=\frac{v-u}{t}.$$

Usually, several pairs of values of x_1 and x_2 may be obtained from each dotted tape. Acceleration is calculated from each pair and is tabulated as below :

Table for Inclination No. 1

S.N.	x_1 (cm)	x_2 (cm)	x_2-x_1 (cm.)	$f=\frac{v-u}{t}=\frac{x_2-x_1}{t}$
1.				
2.				
3.				
⋮				

$\therefore$ Mean $f=$.......

Result. The acceleration f is constant and also it is clear from the last column of the observation table that the relation

$$f=\frac{v-u}{t}$$ is true.

Similar results are obtained by drawing observation tables which correspond to different inclinations of the runway and hence to different values of acceleration f.

Precautions. (1) Same as in experiment No. 2 (method I) of §8·03.

(2) The paper tape may be fixed with the trolley with quick-fix.

(3) The ticker-tape vibrator should be fixed properly with the board.

Note. For the case of uniformly accelerated motion, the velocity-time graph is a straight line. This line can be drawn by compiling the tapes cut between every 10 dots as shown in Fig. 8.8.

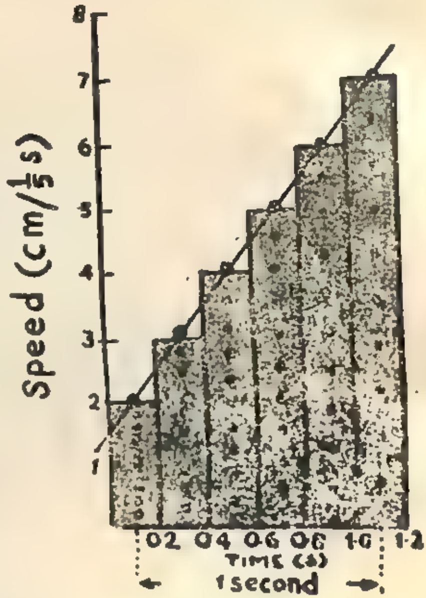


Fig. 8.8. Strips are cut out of the dotted tape, between 10 successive dots and these are arranged to get velocity time graph.

Method 3. To verify the relation $v=u+ft$. by "Falling Plate Method".

(1) Apparatus

Glass plate suitable to the dimensions of the apparatus [Fig. 8.9(a)], wick lamp containing spirit and falling plate apparatus.

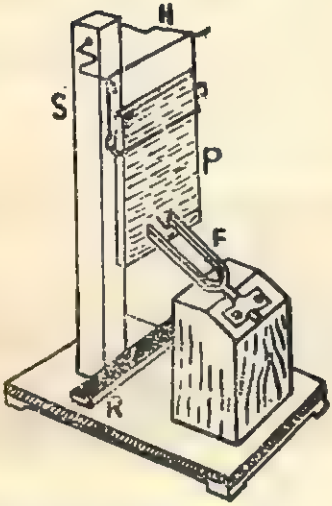
Description of the apparatus. The apparatus consists of a glass strip or a glass plate (P) which is hung with the help of a thread loop and two hooks H fixed in a stand S as shown in Fig. 8.9 (a). An aluminium style is attached to one of the prongs of a tuning fork F with the help of quick fix. The tuning fork is clamped on a wooden block such that the style presses lightly against the glass plate. If the glass plate is smoked and falls freely, then the vibrating style scratches a trace on the plate as shown in Fig. 8.9 (b). The plate falls on a rubber pad R.

(2) Procedure

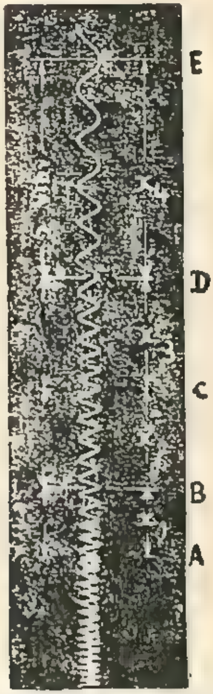
(1) Burn a wick lamp of spirit and move the surface of the glass plate in its flame. In this way the glass plate is **Smoked.**

(2) Hang the smoked glass plate with a thread loop as shown Fig. 8.9 (a). Adjust the tuning fork such that its style presses

lightly on the smoked plate. In this position the two prongs should be almost in a horizontal plane.



(a) Falling plate apparatus



(b) Smoked plate marked by the vibrating style when the plate was falling freely.

Fig. 8.9.

(3) Set the tuning fork into vibration. The style should trace a horizontal line on the smoked glass plate.

(4) Now burn the thread loop. The plate will fall and the vibrating tuning fork will scratch a trace as shown in Fig. 8.9 (*b*).

(5) All the above steps may be repeated with other smoked glass plates.

(6) Note the frequency (n) of the tuning fork. Time taken by the plate to fall through a distance equal to the *wave length* is $1/n$ sec.

(7) Measure the distance for successive five wave lengths as shown in Fig. 8.9 (*b*). Let these distances be x_1, x_2, x_3...etc.

Now proceed for the calculation of the uniform acceleration as in the previous experiment *i.e.* ticker-tape vibrator method. In this case the uniform acceleration is nothing but acceleration due to gravity *i.e.* 'g'.

QUESTIONS

Complete the following sentences by selecting suitable word from the brackets :–

(*i*) Distance travelled by a body is a......quantity. [vector, scalar]

(*ii*) Displacement of a body is a......quantity. [scalar, vector]

(*iii*) A force......on a body moving with a uniform velocity. [acts, does not act]

(*iv*) Most of the moving bodies which we come across in daily life, move with......speed. [uniform, non-uniform]

(*v*) A body falling freely under gravity has a uniform ...... [velocity, speed, acceleration]

(*vi*) The slope of the distance time graph is...... [acceleration, velocity]

(*vii*) The slope of velocity-time graph is....... [force, acceleration]

VIVA-VOCE for the Experiment "to verify $v=u+ft$."

(1) How do you define velocity ?

(2) What is the difference between velocity and speed ?

(3) What is the relation between acceleration and velocity ?

(4) What is the relation between force and acceleration ?

(5) What precautions do you take in performing the experiment ?

(6) Why the least count of the stop watch should be small ?

(7) If a body is falling freely under gravity then explain why a stop watch is replaced by a tuning fork or a ticker tape vibrator for measuring the time intervals ?

(8) Explain how the personal error in measuring small intervals of time is removed by using a ticker tape vibrator ?

9

Balance and Weighing

§ 9.01. Points to Remember.

1. Weighing. A balance is used to measure the mass of a body by comparing it with some standard mass. This process of comparing masses is called *weighing* and the standard masses used for the purpose are usually called "standard weights" or simply "weights"*.

2. Principle of weighing by balance. A balance works on the principle of moments. To understand this, let S and S' be the masses of the pans and 'a' and 'b' be the lengths of arms of the balance respectively as shown in Fig. 9.1. If the centre of gravity of the beam be at a distance x from the fulcrum F and the beam be horizontal without any extra weights on the pans, than from the principle of moments :

$$s.g.a + w.g.x = s'.g.b \quad \text{....(1)}$$

where w is the mass of the beam and g is the acceleration due to gravity.

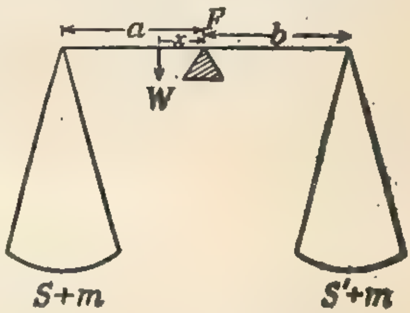


Fig. 9.1. Principle of balance.

If the mass m of a body is to be determined then it is put on the left pan and suitable standard weights m' are placed on the right pan so that the beam is again horizontal. By applying the principle of moments under this condition we get

$$(s+m).g.a + w.g.x = (s'+m').g.b.$$

or

$$s.g.a + m.g.a + w.g\,x = s'.g.b + m'.g.b. \quad \text{....(2)}$$

Subtracting equation (1) from (2) and then cancelling g from both the sides we get

$$m.g.a = m'gb$$

or

$$m.a = m'b \quad \text{...(3)}$$

* The word "weights" is misnomer, instead, it should have been "Standard mass". However, the word "weight" is used in this book just to keep our terms in tune with the common language.

The most convenient method of weighing is in which $m=m'$. From equation (3), m and m' can be equal only when

$$a=b \qquad \text{...(4)}$$

When $a=b$, then $x=0$ ...(5)

provided the beam is uniform. Also, then, from equation (1),

$$s=s' \qquad \text{...(6)}$$

A balance which posseses the qualities defined by equations (4), (5) and (6) is said to be a *true balance*. Hence for a true balance the following conditions are there :

(*i*) The arms should be of equal lengths.

(*ii*) The C.G. of the beam should be at the fulcrum *i.e.*, at its centre. More suitably, the C.G. should be vertically below the fulcrum to make the beam more stable.

(*iii*) The pans should be of equal masses.

3. **False balance.** In actual practice all the above mentioned three conditions of a true balance may not be satisfied. Such a balance which does not satisfy either one, or two or all the three conditions of a true balance, is called a **false balance.**

4. **Correct weighing by False balance.** It is clear from the discussion of the points (2) and (3) mentioned above that the correct mass of a body will not be equal to the standard weight with which it is compared on a false balance. Now the question arises how to find the correct mass of a body by a false balance. We may divide this aspect of weighing into two parts as under :

(*i*) How to determine the correct mass of a body by weighing it on a false balance whose nature of defect is **known.** For the known nature of defects of a false balance the methods used for the correct determination of mass are "Gauss's Method" which is also known as the "Method of double Weighing" and Borda's method of substitution.

(*ii*) How to determine the correct mass of a body by weighing it on a false balance whose nature of defect is **not known.** Under such cases only "Borda's method of subtitution" is used.

These two methods are discussed in detail in the following articles.

§ 9.02. Gauss's method or method of double weighing.

(*i*) *When the scale pans are of unequal mass s_1 and s_2 but the arms are of equal length and C.G. of the beam is at its centre.*

Place the body in one pan and weigh it with standard weights placed in the other pan. Suppose this weight comes to m_1. Now place the body in the other pan and weigh it again in the similar way. Suppose the weight comes to be m_2. Let m be the true mass of

the body. Taking moments* about the fulcrum in the two cases, we have

$$(s_1+m)\ a.g=(s_2+m_1)a.g$$

or $$(s_1+m)=(s_2+m_1) \qquad ...(7)$$

and similarly, $$(s_1+m_2)=(s_2+m) \qquad ...(8)$$

subtracting equation (8) from (7), we get

$$m-m_2=m_1-m$$

which may be put as,

$$m=\frac{m_1+m_2}{2} \qquad ...(9)$$

It is clear from equation (9) that the true mass is the arithmetic mean of the two false weights m_1 and m_2.

(ii) *When the arms are of unequal lengths a and b but the scale pans are of equal mass s and mass of the beam is negligible.*

Place the body of true mass m in one pan and let it be balanced by standard weights m_1, placed in the other pan. The weight of the beam is supposed negligible such that the moment produced by it is zero. Applying the principle of moments in this case we get

$$(m+s)\ a.g=(m_1+s)\ b.g$$

or $$ma+sa=m_1b+s.b. \qquad ...(10)$$

Now the body is placed on the other pan and the beam is balanced by the standard weights m_2. In this case we get

$$(m+s).b.g=(m_2+s).a.g$$

or $$mb+s.b=m_2.a+s.a \qquad ...(11)$$

Adding equations (10) and (11) we get

$$ma+mb+sa+s.b=m_1b+m_2a+s.a+s.b$$

or $$m(a+b)=m_1b+m_2a$$

$$\therefore \quad m=\frac{m_1b+m_2a}{a+b} \qquad ...(12)$$

(iii) ***When the arms are unequal and the scale pans are of unequal mass such that the beam balances** when there are no weights on the pans.***

For such cases let a and b be the lengths of the arms of a balance with pans of masses s_1 and s_2 respectively such that $s_1.a.g=s_2.b.g$. While writing this formula, the mass of the beam has been supposed to be negligible. To determine the correct mass m of a body, it is placed in the pan S_1 and it is counterpoised by the standard weights m_1. By applying the principle of moments in this case, we get

$$(m+s_1)\ a\ g=(m_1+s_2)\ b.g$$

or $$ma+s_1.a=m_1b+s_2\ b$$

Since $$s_1.a.=s_2b.$$

we get, $$m.a=m_1.b \qquad ...(13)$$

---

* Moments are considered when the beam of the balance is horizontal.

** *i.e.*, the beam remains horizontal.

Now the body is placed on the pan s_2 and its incorrect mass m_2 is determined in the similar way. Thus we get

$$(m_2+s_1)\, a.g=(m+s_2)b.g.$$

or
$$m_2.a+s_1.a=m.b+s_2.b.$$

or
$$m_2.a=m\, b \qquad ...(14)$$

Dividing equation (12) by (13) we get

$$\frac{m}{m_2}=\frac{m_1}{m}$$

or
$$m^2=m_1 m_2$$

or
$$m=\sqrt{m_1 m_2} \qquad ...(15)$$

One may arrive at the same result as given by equation (15) even if the weight of the beam is supposed to act a point away from the fulcrum. It is clear from equation (15) that the true mass m of a body is the geometric mean ($\sqrt{m_1 m_2}$) of the two incorrect masses determined.

§9.03. Borda's Method of Subsititution.

This method is better and more convenient than the "Gauss's Method" due to two reasons as under :

(*i*) Borda's method is applicable for every kind of false balance *i.e.* whether its defect is known or unknown.

(*ii*) Borda's method gives the true mass of a body *directly* without the use of any formula or calculation.

Method

In this method the body to be weighed is placed in the left pan and it is counterpoised by sand or by any other convenient material placed in the right pan. The body is now replaced by "standard weights" such that the beam is again horizontal. Care should be taken not to change the counterpoise. Thus *the body in the first case and the 'standard weights' in the second case balance the same counterpoise under the same conditions and hence they are equal.* Thus the mass of the body is obtained directly and is equal to the mass of the "standard weig.

§9.04. Pupil's Experiment No. 3 : Method I.

Aim. To design a balance with unequal arms and measure **correct** mass by using it (Borda's Substitution method).

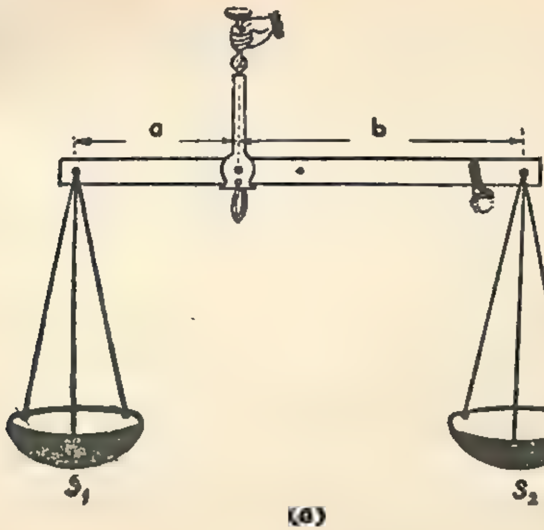
Apparatus. A rod or beam of wood or iron, chord, two aluminium or iron or any other pans, arrangement to bore holes and standard weights.

Theory. See § 9.03.

Designing the balance.

Procedure. (*i*) Draw three holes in a beam, two of them near the ends and the third few centimetres away from its mid-point.

(*ii*) Draw three equidistant holes in each pan near their rim and attach the chords to these plates through these holes as shown in Fig. 9.2 (*a*).



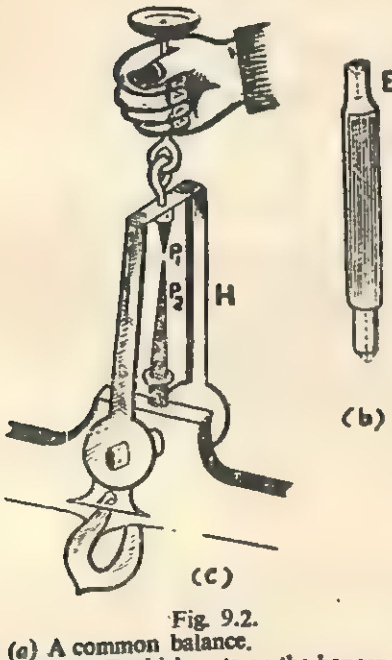


Fig. 9.2.
(*a*) A common balance.
(*b*) Edge E which rests on the hanger H.
(*c*) Hanger H.

(*iii*) Make a 'V'-shaped edge as shown in Fig. 9.2 (*b*) out of a nail with the file. This should fit in tighty in the central hole of the beam.

(*iv*) Make an arrangement as shown in Fig. 9.2 (*c*) out of an iron strip from where the beam may be hung through its knife-edge. The purpose of this arrangement is to hang the beam and to check its **horizontality**. One pointer P_2 is attached to the beam above the knife edge and another P_1 is attached to the hanger. When the beam is horizontal the tips of the two pointers are coincident.

Weighing. (*i*) Place the body to be weighed on the left pan and counterpoise it by sand or any other suitable material placed on the right pan so that the beam is horizontal.

(*ii*) Without disturbing the contents of the right pan, the body in the left pan is replaced by "standard weights" in such a way that the beam is again horizontal. The horizontality of the beam is adjusted by adjusting the "standard weights".

The body and the "standard weights" balance the same amount of sand and hence the mass of the body is given by the standard weights.

(*iii*) Steps (*i*) and (*ii*) are repeated by putting the body, now, on the right pan and the sand on the left pan. In this way also the weight of the body is determined.

Observations.

(*i*) Mass of the standard weight when the sand is in the right pan $(m_1)=$...g.

(*ii*) Mass of the standard weight when the sand is in the right pan $(m_2)=$...g.

$\therefore$ Mean mass of the body$=\dfrac{m_1+m_2}{2}$...g.

Result. Mass of the body with the balance of unequal arms which I have designed is equal to ...g.

Precautions. (*i*) Horizontal position of the beam must be checked properly by the coincidence of the tips of P_1 and P_2.

(*ii*) The hanger should suspend freely *i.e.* there should be no tilt in its position due to the pressure by fingers etc. on it.

(*iii*) There should be no magnet near the balance if the balance has iron parts.

Method 2

Aim. To design a balance with unequal arms and to use it for measuring the correct mass of a body by "Gauss's Double Weighing" method

Apparatus. As mentioned in method I except for the sand.

Theory. Read §9.02 part (*iii*).

Procedure

(*i*) **Designing the balance.** See method I. In designing the balance care should be taken that the **beam is horizontal when no weights are placed on the pans.**

(*ii*) Place the body of true mass m to be weighed on the left pan and balance it by placing standard weights m_1 on the right pan such that the beam is horizontal.

(*iii*) Now the body is placed on the right pan and it is balanced by placing standard weights on the left pan such that the beam is again horizontal. Note this standard weight m_2.

Observations

Incorrect mass m_1 of the body when placed in the left pan =...g.

Incorrect mass m_2 of the body when placed in the right pan =...g.

Calculation. Substitute the values of m_1 and m_2 in the equation $m=\sqrt{m_1 m_2}$ and calculate the correct mass m of the body

Result. The correct mass of the body is=...g.

Relative merits of the two methods.

Out of the two methods discussed above the **Borda's** method is preferable because of the reasons already **mentioned** in the **beginning** of §9.03.

QUESTIONS

Complete the following sentences by **selecting suitable** words from the brackets :—

(*i*) A balance works on the principle of......
[Couple, moments, gravitational pull]

(*ii*) Horizontality of the beam of a balance is checked by......
[eye estimation, the coincidence of the pointer of the beam and the hanger]

(*iii*) For a true balance the correct mass of a body is......the standard weight when a magnet is placed (on the earth) below the iron pan containing the body.
[equal to, less than, more than]

(*iv*) Using a balance of unequal arms and pans of equal mass, the true mass of a body is given by the...... [formula $\frac{m_1+m_2}{2}$, formula $\sqrt{m_1 m_2}$, Borda's method of substitution]

(*v*) In the absence of knowledge about the type of defect in a balance, the true mass of a body is determined by......
[Gauss's method of double weighing, Borda's method of substitution]

VIVA-VOCE ON PUPIL'S EXPERIMENT No. 3

(1) What do you mean by the mass ?
(2) What is the difference between the mass and the weight of a body ?
(3) Do you measure weight while you weigh a body on a balance with two pans ?
(4) Explain the types of false balance.
(5) Which method will you apply to measure the mass correctly in case you do not know the type of defect in the false balance ?
(6) Why Borda's method is preferred over the Gauss's method ?
(7) How do you check whether the beam of the balance is horizontal or not ?
(8) Is it essential to check the horizontality of the beam for accurate weighing ?

10

Wet and Dry Bulb Hygrometer

§10.01. Points to Remember

(*i*) **General.** Water vapour is more or less always present in air due to evaporation from the surfaces of water from the seas, rivers, lakes, the moist earth etc. The rate at which moisture evaporates from our body depends upon (*a*) the temperature of the surroundings, (*b*) the amount of water vapour already present in the atmosphere and (*c*) the rate of movement of air over the skin.

(*ii*) **Absolute Humidity.** It is the actual amount of water vapour present at a given temperature in 1 cubic metre of the atmospheric air.

(*iii*) **Relative Humidity (R.H.).** Depending upon the variables, the relative humidity may be defined in different forms but essentially, all the definitions are derived from the following :

$$\text{R.H.} = \left[\frac{\left[\begin{array}{c}\text{Mass of water vapour in a given volume of}\\ \text{air at any temperature}\end{array}\right]}{\left[\begin{array}{c}\text{Mass of water vapour required to saturate the}\\ \text{same volume of air at the same temperature}\end{array}\right]}\right] \times 100$$

It is customary to represent R.H. in percentage. Other definition is as under :

$$\text{R H.} = \frac{\text{Saturated vapour pressure at dew point}}{\text{Saturated vapour pressure at room temperature}} \times 100$$

(*iv*) **Dew point.** It is the temperature at which the amount of water vapour present in a given volume of air, is just sufficient to saturate it.

§10.02. Pupil's Activity No. 2 : Method No. 1

Aim. To assemble a "wet and dry bulb" hygrometer and to determine the relative humidity.

Apparatus. Two celsius thermometers each of half degree accuracy, thread, a retort stand, muslin cloth, a beaker containing water and a wooden frame.

TABLE.—RELATIVE HUMIDITY

Relative Humidity (Per Cent)

Dry Bulb Reading (Degree Celsius) $= t_d$

Depression in the Reading of Wet Bulb (Degree Celsius) $= t_d - t_w$

t_d	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
50	94	89	84	79	74	77	65	61	57	53	50	46	42	39	36	33	30
48	94	89	84	79	74	69	65	60	56	52	48	45	41	38	34	31	29
46	94	89	83	78	73	68	64	59	55	51	47	43	40	36	33	29	26
44	94	88	83	78	72	68	63	58	54	50	46	42	38	34	31	27	24
42	94	88	82	77	72	67	62	57	53	48	44	40	36	32	29	25	22
40	94	88	82	76	71	66	61	56	51	47	42	38	34	30	27	23	20
38	94	87	81	75	70	65	59	54	50	45	41	36	32	28	24	21	17
36	93	87	81	75	69	63	58	53	48	43	39	34	30	26	22	18	14
34	93	86	80	74	68	62	56	51	46	41	36	32	27	23	19	15	11
32	93	86	79	73	67	61	55	49	44	39	34	29	24	20	16	11	7
30	93	85	78	72	65	59	53	47	42	36	31	26	21	16	12	8	3
28	92	85	77	70	64	57	51	45	39	33	28	23	18	13	8	3	
26	92	84	76	69	62	55	49	42	36	30	25	19	14	8	3		
24	91	83	75	68	60	53	46	39	33	27	21	15	9	4			
22	91	82	74	66	58	51	43	36	29	23	16	10	4				
20	91	81	73	64	56	48	40	33	25	18	11	4					
18	90	80	71	62	53	45	36	29	21	13	6						
16	89	79	69	60	50	41	32	24	16	7							
14	89	78	67	57	47	37	28	18	10	1							
12	88	76	65	54	43	32	22	12	3								
10	87	74	62	50	38	27	16	5									
8	86	72	59	46	33	21	9										
6	85	70	55	41	28	14											
4	83	67	51	36													
2	82	64															

Procedure. (*i*) *Thermometer test*: Dip the bulbs of two thermometers in water in a beaker and see if both of them give the same temperature. If there is a difference in their readings, change them to be sure that both the thermometers are *accurate*.

(*ii*) Remove the dirt or grease, if any, from the piece of muslin cloth *M* by washing it.

(*iii*) Now tie one end of the cleaned muslin cloth by wrapping it over the bulb of one of the thermometers *W*. Hang the thermometers from the iron stand as shown in Fig. 10.1.

(*iv*) Place the beaker *B* containing water on platform of the stand and adjust the height of the rod from which two thermometers are hung in such a way that only the lower end of the muslin cloth dips in water. The bulb of thermometer *W* should not dip in water. Water will rise to the bulb through the muslin cloth and will evaporate which will produce cooling effect. Thus the temperature recorded by the thermometer *W* will be less than the room temperature. The thermometer *W* is called "Wet bulb thermometer" and *D* is called "Dry Bulb thermometer". Thus this pair of thermometers becomes "Wet and Dry bulb" hygrometer. Place the wooden frame between the two thermometers so that the evaporation from the muslin cloth does not affect the reading of the thermometer *D*. Also the apparatus should not be placed near an open window or under a fan.

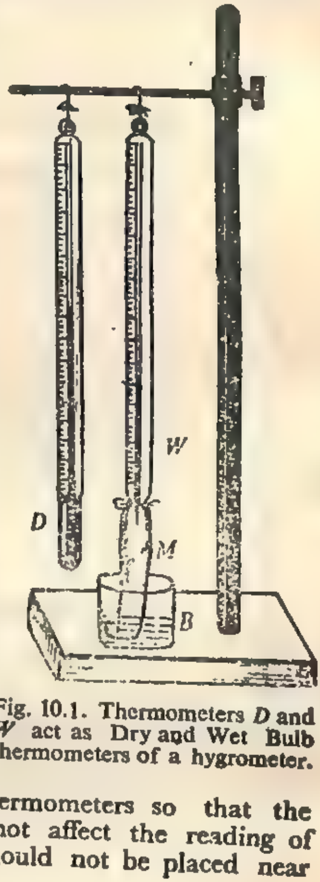


Fig. 10.1. Thermometers *D* and *W* act as Dry and Wet Bulb thermometers of a hygrometer.

(*v*) Note the readings of the thermometers *W* and *D*. The reading of the thermometer *W* should be recorded after every five minutes, till its reading becomes minimum and constant.

(*vi*) Note the reading of thermometer *D* at the end of the experiment also.

(*vii*) Record the observations as given below and then calculate R.H. with the help of the **relative humidity** table (page 77).

Observations.

(*a*) (*i*) Reading of thermometer *D* in the beginning $=t_1$°C$=$...°C

(*ii*) Reading of thermometer *D* at the end $=t_2$°C$=$...°C

(*b*) Reading of thermometer *W* (Wet bulb).

S. No.	Wet bulb reading after every 5 mints.
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	
20.	

Calculations.

Mean reading of thermometer D *i.e.* Dry bulb $t_d=\frac{t_1+t_2}{2}=\ldots°C$

Constant reading of the Wet bulb thermometer $W=t_w=\ldots\ldots$

$\therefore$ Difference $t_d - t_w = \ldots°C$.

Use of the relative humidity table. Choose that column of the table at the top of which this *depression* (t_d-t_w) is written and then come down along this column until the column level *i.e.*, the horizontal row at its extreme left indicates the Dry bulb thermometer reading t_d. The position at which this *column* and the *row* cross each other, indicates the *percentage relative humidity*.

Result. The relative humidity on...... (date) at ... . (time) is......% at......(place).

Precautions.

(*i*) Muslin cloth should be cleaned before use.

(*ii*) The bulb of the "wet bulb thermometer" should not dip in water otherwise both the thermometers will record the same temperature.

(*iii*) Apparatus should not be placed under a fan or on open window.

N.B. The same experiment may be conducted using the conventional wet and dry bulb hygrometer as shown in Fig. 10.2.

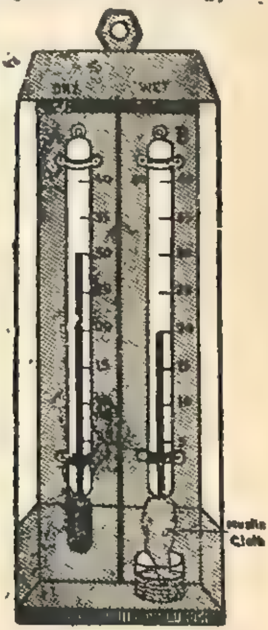


Fig. 10.2. Wet and Dry Bulb Hygrometer.

Method 2.

The most convenient method for measuring relative humidity is by the use of the

Sling psychrometer which is a slight **modification** of "wet and dry bulb hygrometer". This instrument also consists of two identical thermometers mounted on a light frame which can be rotated rapidly in air as shown in Fig. 10.3. One of the thermometers, *i e*, the wet bulb, is covered with a wick which is saturated with water before rotating. The other thermometer *i.e*, dry bulb thermometer has no wick. As the instrument is "whirled" or slung through the air, evaporation from the wick occurs, cooling the bulb of the "wet bulb thermometer". Its temperature reading falls below that of the dry bulb thermometer. The difference between the readings of the two thermometers gives the relative humidity on using the relative humidity table.

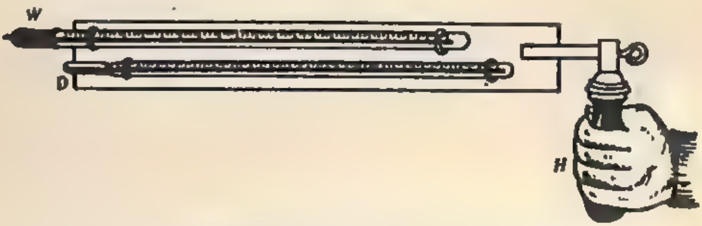


Fig. 10.3. Sling psychrometer used by meteorologists for relative humidity.

QUESTIONS

Complete the following sentences by picking up proper words from the brackets :—

(i) Absolute humidity is the......of water vapour actually present in......
(atmosphere, mass, volume, air)

(ii) The air containing water vapour is......the dry air at the same temperature and pressure. (as dense as, denser than, less dense than)

(iii) If the difference between the readings of the dry bulb and wet bulb be large, it shows greater degree of......of the air. (wetness, dryness)

(iv) Heating the air in a room causes the relative humidity to be... ..
(increased, decreased)

(v) No dew is formed when the sky is...... (clear, cloudy)

(vi) No dew is formed when the night is...... (calm, windy)

(vii) Rate of dew formation increases when the relative humidity is......
(high, low)

(viii) When the relative humidity is very high, we feel.........
(pleasant, oppressed)

(ix) When a wet and dry bulb hygrometer is placed under a working fan the reading of the wet bulb will be......than the actual reading and the result for the relative humidity will be......than the correct value.
[more, less]

(x) When it is raining, the readings of the wet bulb and the dry bulb of a hygrometer are......
(very much different, equal)

(xi) When the wet bulb of a hygrometer is dipped into water, the difference of the readings between the dry bulb and wet bulb is......
(less than the actual, larger than the actual, zero)

(xii) ....air is necessary for spinning and weaving cotton. (Dry, Wet)

PART II

For Class X

CHAPTERS

11. Light.
12. Electricity and Magnetism.
13. Emission of Electrons (Photo-Electric ity and Electronics).
14. Heat and Energy.
15. Elementary Training in Soldering.
16. Elements of Workshop Practice.

11

Light

1. DISPERSION

§11.01. Points to Remember

(1) **Prism.** It is the wedge-shaped piece of a transparent material bounded by three planes inclined to each other. The *line* along which any two transparent faces of the prism meet is called the *refracting edge of* the prism and the angle between these faces is called the refracting angle as shown in Fig. 11.1. The section of a prism by a plane perpendicular to the refracting edge is called the *principal plane.* Thus ABC or $A'B'C'$ are principal planes. The face of the prism opposite to its refracting edge is called the *base.*

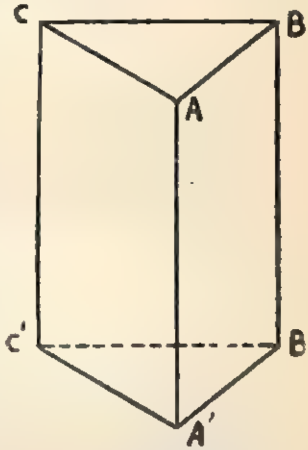


Fig. 11.1. A Glass Prism.

(2) **Dispersion.** The sun rays appear yellowish white to the human eye but actually it is composed of **seven colours**. When the sun rays pass through a prism they are not only *deviated* but also separated into their constituent colours. *The separation of a composite ray, (consisting of many colours) into its constituent colours is called* **dispersion.**

§11.02. Demonstration Experiment No. 1 (*a*).

Aim. To demonstrate the dispersion of sunlight using a glass prism.

Apparatus. A glass prism, a plane mirror and black paper.

Procedure. (1) Cut a small slit in the black paper and paste this paper on the plane mirror M such that only the slit portion permits the reflection of light as shown in Fig. 11.2.

(2) Throw sunlight with the help of the mirror M inside the class room.

(3) Place the prism in the path of the sun rays in the class room in such a way that the rays fall on one of its *faces*. Adjust the inclination of the face by rotating the prism. At some position of the prism, you will observe a coloured belt on the wall facing the sun rays. The coloured belt may also be observed either on the ceiling of the room or on the floor.

(4) Observe the colours, in the belt. You will find seven colours in it in the following order : Violet, Indigo, Blue, Green, Yellow, Orange and Red. As an aid to memory, the order of the colours may be remembered by the word **Vibgyor**. However, the colour belts are not seen distinctly, *i.e.*, there is overlapping of colours at the edges of the belts.

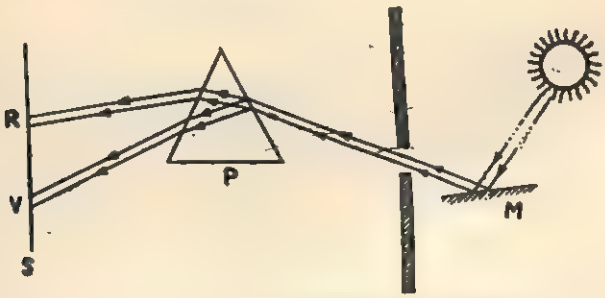


Fig. 11.2. **Demonstration of Dispersion of Sun Rays.**

Conclusion. Sunlight consists of seven colours (Violet, Indigo, Blue, Green, Yellow, Orange and Red). These colours are separated along different directions after the rays pass through a prism. Also it is clear that when light passes through a prism **Dispersion** and **Deviation** of light take place simultaneously.

Demonstration Experiment No. 1 (*b*).

Spectrum can also be shown to the students without a conventional prism. Set a tray of water in bright sunlight. Lean a rectangular plane mirror against an inside edge of the tray. Adjust the mirror's inclination so that a colour band or spectrum appears on the wall. In this case water between the mirror surface and its own surface forms a water prism which causes dispersion.

2. HUMAN EYE

§11.03. Normal Eye (Vision).

The edge of the crystalline lens of human eye is surrounded by **Ciliary Muscles**. To see a nearby object clearly, the ciliary muscle contracts to bulge out the lens. The contraction results into the decrease in the focal length of the lens and thus the image of the nearby object is formed at retina.

When ciliary muscles relax the edges of the lens are pulled due to tension in the **Suspensory Ligaments**. Thus the lens is

flattened which results into the increase in its focal length. In this way the distant objects are brought to focus at the retina.

The normal eye is most relaxed when it is focused for parallel rays *i.e.* for objects far away. Thus the **Far Point** for a normal human eye is **Infinity.** To study the details of an object, however, the object should be brought close to the eye. The reason for this being the fact that closer the object to the eye, the larger is the image formed on the retina. A distance of about 25 cm. is found to be the distance of most **Distinct Vision** for a normal eye. This distance of 25 cm. is called the **Least Distance of Distinct Vision.** A point at a distance of 25 cm. from the eye-lens is called the **Near Point.** Prolonged observation at a distance of 25 cm. or less will result in a considerable amount of fatigue and eye strain.

§11.04. Defects of Vision.

The power of *accommodation* possessed by the normal human eye is such that it can clearly see the objects placed anywhere between infinity and its **Near Point** (*i.e.* 25 cm.). But as the person grows older the *accommodation* becomes more and more difficult because the eye lens tends to *harden* and the muscles that control it grow *weaker*. The rate of hardening of the lens varies from individual to individual.

In some children also the vision is defective because of improper shape of the **eye ball.** The common defects of vision in human eye are the following : (*i*) Long or far sighted eye (*ii*) Short or near sighted eye (*iii*) Presbyopia and (*iv*) Astigmatism.

(*i*) **Long Sightedness.** Long sightedness is caused by the *eye-ball being too short* as shown in Fig. 11.3 (*a*). If a book is held at 25 cm. (*i.e.* at the *near point N* of a normal eye) from such an eye it will appear blurred because for this distance a clear image is formed at a point I only behind the retina as shown in Fig. 11.3 (*a*) and (*b*). The *Near Point* for such an eye is at *O* which is farther than 25 cm. as shown in Fig. 11.3 (*c*). This kind of defect of vision is also called *Hypermetropia.* This defect of vision is also called *far sightedness* because the person can see clearly the **far off** objects.

The reader keeps the book farther from his eye to see the print distinctly in this type of defect when he does not use specs as shown in Fig. 11.3 (*a*).

Correction. A *long sighted* eye is corrected by the use of a convergent lens of suitable focal length. This convergent lens converges the rays entering the eye just sufficiently to make the rays appear as if these are coming from the eye's own near point *O* as shown in Fig. 11.3 (*d*).

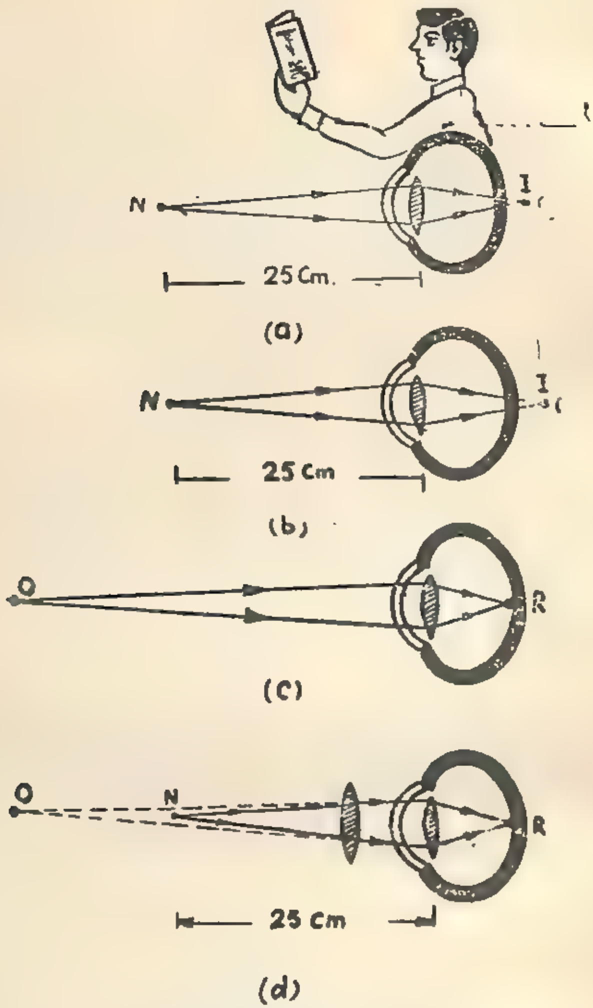


Fig. 11.3. For a hypermetropic eye the eye-ball is too short (Long-sight defect).

N⟶Near Point for Normal Eye.
O⟶Near Point for the defective eye.
R⟶Retina.

(*ii*) **Short Sightedness.** The short sightedness is caused by the *eye-ball being too long* or too much flattened as shown in Fig. 11.4 (*a*). For such an eye the parallel rays, coming from infinity, are focused at a point I in front of the retina as shown in Fig. 11.4 (*a*) and (*b*). The actual **Far Point** F for such an eye may be only a metre or so as shown in Fig. 11.4 (*c*). This defect of vision is known as **Myopia.** This defect of vision is also called *Near Sightedness* because the person can see the near objects clearly.

The reader keeps the book closer to see the print distinctly when he does not use specs [Fig. 11.4 (*d*)].

Correction. A short sighted eye is corrected by the use of a divergent lens of suitable focal length. This lens diverges the rays entering the eye just sufficiently to make the rays appear as if these are coming from eye's own *Far Point F* as shown in Fig. 11·4 (*d*).

Calculations for the Focal Length. As we have discussed in the above article, the defective vision is corrected by the use of a lens. To know the *nature* and *focal length* of the lens to be used let us understand the following calculations

The formula used for these calculations is $1/f=1/v-1/u$. To understand this formula read §11.13 points (3) and (4). *With use of the lens the image should be formed at the point where the eye can see distinctly without the use of a lens.* Thus v should always correspond to the *near point* or the *far point* of the defective eye as the case may be.

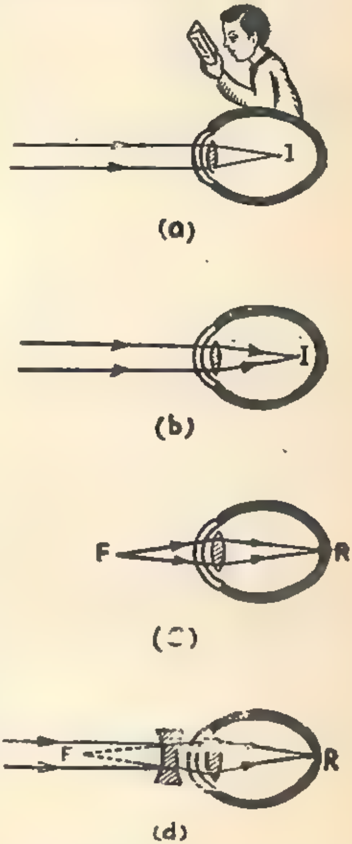


Fig. 11.4. For a myopic eye, the eye ball is elongated or it is too long. (Short-sight defect.)

Far point is at infinity for a normal eye but for the defective eye it is at F.

R—→Retina.

Problem 1. A myopic eye is not able to see objects beyond 2 metres. Find the nature, the focal length and the power of the correcting lens.

In this case,

$$u=-\infty, \quad v=\text{the far point}=-2 \text{ metres.}$$

$\therefore$ $$1/f=-\tfrac{1}{2}+1/\infty=-\tfrac{1}{2} \qquad \text{(Since } 1/\infty=0)$$

or $$f=-2 \text{ metres.}$$

Power of the lens $P=1/f=-0{\cdot}5$ Dioptre.

Ans. Concave lens, 2 metres and $-0{\cdot}5$ Dioptre.

Problem 2. A person can see objects only when they are brought to a distance of 80 cm. from the eye while a person with normal eye sight can see clearly at 160 cm. Find the nature, the focal length and the power of the correcting lens to be used.

Defect is myopia,

$$v=-80 \text{ cm.} ; u=-160 \text{ cm.}$$

$$\therefore \quad \frac{1}{f}=-\frac{1}{80}+\frac{1}{160}=-\frac{1}{160}$$

$$\therefore \quad f=-160 \text{ cm.}$$

and power of the lens $P=\dfrac{1}{f \text{ (in metres)}}$

$$=-\frac{1}{1{\cdot}6}=-0{\cdot}625 \text{ Dioptre}$$

Ans. Concave lens, -160 cm., $-0{\cdot}625$ Dioptre.

Problem 3. A person cannot see objects nearer than 75 cm. while the person with normal eye sight can see up to 25 cm. Find the nature, the focal length and the power of correcting lens used.

The defect is Hypermetropia.

$$v=-75 \text{ cm}, \qquad u=-25 \text{ cm.}$$

$$\therefore \quad \frac{1}{f}=-\frac{1}{75}+\frac{1}{25}=+\frac{2}{75}$$

$$\text{or} \quad f=+\frac{75}{2}=+37{\cdot}5 \text{ cm.}$$

and power of the lens $P=\dfrac{1}{f \text{ (in metres)}}$

$$=\frac{100}{75/2}=\frac{200}{75}=+\frac{8}{3}$$

$$=+2{\cdot}66 \text{ Dioptre.}$$

Ans. Convex lens, $+37{\cdot}5$ cm. and $+2{\cdot}46$ Dioptre.

(*iii*) **Presbyopia.** In old age the ciliary muscles become weak and the eye is not able to accommodate up to the normal near distance of distinct vision. In other words the near distance of distinct vision of the eye is *increased*. If there is no defect in the eye ball or the eye lens, the person suffering from presbyopia will have his far sight

normal but he will have difficulty in seeing the near objects or reading the book, etc. The defect is remedied by the use of a convex lens of such focal length that when an object is placed at the normal near distance of 25 cm., its virtual image is formed at the increased distance of distinct vision of the presbyopic eye. It must be noted that the person suffering from presbyopia uses convex lens spectacles for seeing the objects placed at the near distance of distinct vision or for reading purposes only, while the hypermetropic eye needs the convex lens spectacles for all distances. When a myopic eye loses the power of accommodation in old age, it will need both types of glasses,* concave for rectifying the distant vision and convex for reading purpose.

(*iv*) **Astigmatism.** This defect occurs when the cornea does not have a truly spherical shape. The curvature is not the same in different planes containing the axis of the eye. Thus the focal length of the eye lens is not the same at different planes. The result is that while the normal eye is able to focus the light from all parts of the object to produce a sharp image, the astigmatic eye may form the clear image of points in one plane and not in the other. Thus the person may, for instance, see the vertical wires and not the horizontal ones of a wire gauze. Cylindrical lenses are used to remedy this defect.

§11.05. Demonstration Experiment No. 2.

Aim. To demonstrate various parts of human eye with the help of a **"Descectable Eye Model"**.

Apparatus and Procedure. Discectable model of eye is available from scientific dealers. Various parts may be shown by opening the model. The function of each part may be explained.

§11.06. Suggested Pupil Activity No 1 (*a*).

Aim. To prepare an eye-model with a flask and to show the sight-defects and their corrections with suitable lenses.

Apparatus. Convex and concave lenses of suitable focal lengths, lens holder, a round bottom flask, plasticine, fluorescein solution, a compact source of light, and a thick card board with a small central hole.

Fluorescein Solution.** The path of light rays travelling through a solution of fluorescein is very clearly seen. To prepare the solution, one gram of fluorescein is dissolved in 100 ml. of industrial or methylated spirit.

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* Such lenses are called bi-focal lenses.

** An alternative solution may be prepared by adding a few drops of milk in water.

Theory. This is an important demonstration in which students can see the path of light rays in a model of an eye made in a round bottom flask F containing fluorescein solution as shown in Fig. 11.5 (a). The model shows a **Normal** eye looking at a small luminous object, say a small opening in the compact light source. This image of the luminous point is formed with the lens L_1 Fig. 11.5 (b) at the retina R. The path of the convergent beam is interesting to see. Now with a change of the lens (L_2, L_3), the luminous object may be made to focus either in front of R or farther from R which means now the eye becomes **Short-Sighted** or **Long-Sighted** respectively.

By introducing another suitable lens (L) with the help of the lens holder, the defects may be corrected.

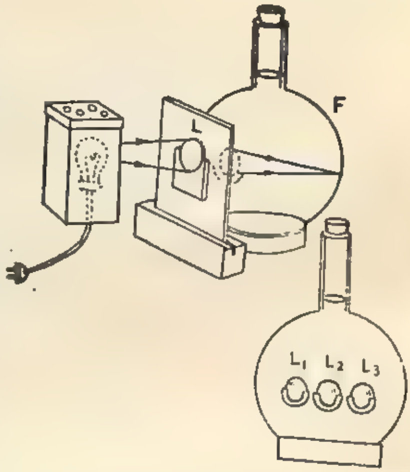


Fig. 11.5. Experiment to study the eye defects and their corrections.

The effect of distance of the object may also be demonstrated.

Choice of Lenses. The success of the demonstration depends upon the choice of the three lenses L_1, L_2, L_3, and two correcting lenses L for the given flask. These lenses are suggested here for a flask of 5 litres capacity and of 21·8 cm. diameter.

The lens L_1 for **Normal Eye** should have a power of +8 Dioptre, the lens L_2 for **Short-Sighted** eye should have a power of +11 D and the lens L_3 for **Long-Sighted** eye should have a power of +5·5 D. In order to facilitate the change from one model to another, the three lenses L_1, L_2, L_3 should be attached side by side along the horizontal equator of the flask with the help of plasticine as shown in Fig. 11.5 (b). Then, rotating the flask by its vertical neck will bring one lens after another into play.

The spectacle lens (L) for correcting the **Short-Sighted** eye should have a power of $-3D$ and the lens for the **Long-Sighted** eye +2·5 D.

Procedure. (1) Fix the lens L_1, L_2, and L_3 on the flask as shown in Fig. 11.5 (b). Fill the flask with very dilute solution of fluorescein and then place the flask on a cork ring as stand. To view the rays clearly, the solution must be dilute.

(2) Set up the light source such that a small luminous opening acts as the object to be viewed. Erect the card with hole in it,

vertically in front of the flask so that the hole is in level with the lenses and serves as an *IRIS*.

Rotate the flask until the $+8\ D$ lens (L_1) is behind the hole and arrange the light source to lie in level with the hole and the centre of the flask F as shown in Fig. 11.5 (*a*). Move the light source until a sharp image of the luminous hole is formed at the point R on the surface of the flask. A small piece of wet paper may be put on the surface of the flask (on the back of R) to make the image on the retina R easily visible.

(3) Keeping the light source fixed, rotate the flask to bring the lens L_2 ($+11\ D$) behind the hole to show short-sightedness. Show how $-3\ D$ lens corrects the short-sighted eye. Now rotate the flask further to bring the lens L_3 ($+5{\cdot}5\ D$) behind the hole to show long-sightedness. Show how $+2{\cdot}5\ D$ lens corrects this defect.

(4) Remove the correcting lens away and rotate the flask to make the eye-model again **Short-Sighted.** Now move the light source until the image is formed at R. Point out that the object has to be *near* to the eye and hence this defect is also called **near-sightedness.** Similarly explain that for a **Long-Sighted Eye** the object has to be kept *far* from eye and hence the defect may also be called **far-sightedness.**

Suggested Pupil Activity No. 1 (*b*).

Examine the spectacles of your **friends and** relatives and ask the power of their lenses. Collect data as to what kind of defect of vision is developed with the growing age.

N.B. Now a days the correcting lens may be fitted inside the eye. Thus the use of the spectacle frame is avoided. Such lenses are called "**Contact Lenses**".

3. CONCAVE MIRROR

§ 11.07. Points to remember.

1 Concave mirror. It is a part of hollow glass sphere with its convex side silvered such that the inner surface becomes reflecting as shown in Fig. 11.6.

2. Curved-mirror terminology. Terms are defined with reference to Fig. 11.7.

(*i*) The *centre of curvature*, C, is the centre of the sphere of which the mirror forms a part.

(*ii*) The *pole*, P, is the centre of the curved surface of the mirror.

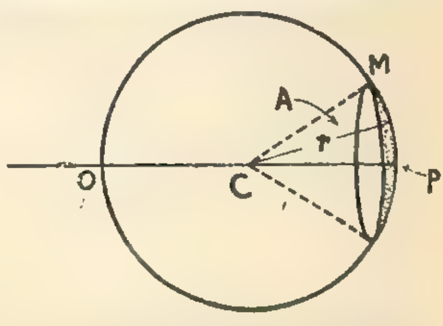


Fig. 11.6. Origin of a concave mirror.

(*iii*) The *radius of curvature*, *r*, is the radius of the sphere of which the mirror forms a part.

(*iv*) The *aperture* is the angular portion, MCN, of the sphere that is included by the mirror. Generally, only a few degrees of the total surface of the sphere is used as the reflecting surface.

(*v*) The *principal axis* is the line PO drawn through the *centre of curvature* C and the *pole* P.

(*vi*) The principal *Focus F* is the point on the principal axis to which rays parallel to the principal axis converge after reflection. The point F is mid-way between C and P as shown in Fig. 11.7.

(*vii*) The *focal length* 'f' is the distance between the pole P and the principal focus F.

(*viii*) The *laws of reflection* which hold good for the plane surfaces are also true for curved surfaces.

(*ix*) The radius of curvature *r* is twice the focal length *f* *i.e.*,

$$\boxed{r=2f}$$

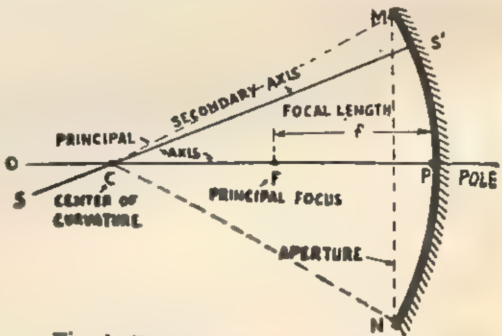


Fig. 11.7. Terminology of curved mirrors.

(*x*) The focal length '*f*', the object distance *u* from the pole and the image distance *v* from the pole are related by the following equation :

$$\boxed{\frac{1}{u}+\frac{1}{v}=\frac{1}{f}}$$

3. Two kinds of images.

Real Image. These images are formed by the actual or *real meeting* of the rays and can be projected on a screen. Real images are always *inverted* with respect to the object and may be either larger or smaller than the object in size.

Virtual Image. These images are not formed by the actual meeting of the rays and cannot be projected on a screen. Virtual images are always *erect* with respect to the object and may be either enlarged or reduced in size.

4. Sign Conventions. There are two kinds of sign conventions. One is called the "New Cartesian" and the other is called the "Real Positive Convention". We shall discuss here only the **New Cartesian Conventions.**

According to this convention—

(*i*) The incident ray is taken from left to right.

(*ii*) All distances are measured from the pole of the mirror as origin.

(*iii*) Distances, measured in a direction *opposite* to the incident ray direction, are taken *negative*.

(*iv*) Distances, measured in the *same direction* as the incident ray are taken *positive*.

Thus in the *New Cartesian Convention*, the focal length of a *concave mirror* is *negative* and that of *convex mirror* is *positive*.

5. **Parallax.** Fix two needles or nails P and Q vertically on a drawing board or on a table. View these pins from the position A so that P appears to be directly behind Q as shown in Fig. 11.8. Now shift your eye to the *left* say to position B, you will observe that the more distant needle P appears to move to the *left* of Q. Similar observation is there when you shift your eye to the right, say to position C.

Thus the object situated at greater distance appears to shift in the same direction as the eye while the object situated nearer the eye, appears to shift in theop posite direction. This apparent shift in the positions of two objects situated at different distances from the eye, for a side way shift in the position of it, is called **Parallax**. Parallax may be removed either by moving Q suitably away from the eye or by moving P towards the eye. When there is no relative shift in the positions of P and Q, for any position of the eye, the parallax is said to be removed. "No-parallax" mothod or "Removal of parallax" is a very popular method to trace the position of image formed by a mirror or a lens.

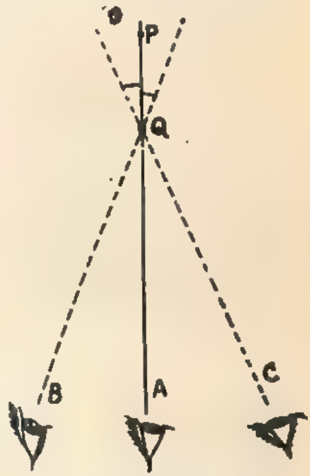


Fig. 11.8. Parallax between P and Q.

6. **Optical Bench.** It consists of a metallic or a wooden bed on which three or four uprights can slide along its length as shown in Fig. 11.9. These uprights are rigid and can be fixed in any position. They carry the optical parts like mirror, object and image needles. These uprights may be given a side motion also so that the pole of the mirror and the tip of the needles may be arranged in the same vertical plane. A millimetre scale is also fitted on the bed along its length so as to read the position of the uprights, sharp *indices* are marked on the bases of the uprights, which help in noting down their positions on the scale. The sketch of a simple optical bench is shown in Fig. 11.9.

7. Index Error or Bench Error and its Correction. In an actual experiment on an optical bench we are required to measure the object and image distances from the pole of the mirror. The distance between the tip of the needles and the pole of the mirror is the *Actual* distance. But we *practically* measure distances between the *indices* with the help of the scale. These distances are called the *observed distances*. The *actual distances* may not be equal to the *observed distances* and hence, corrections must be applied to the *observed distances*. This correction is called *Index Correction.*

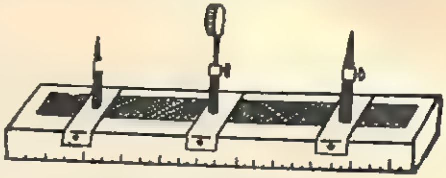


Fig. 11.9. Optical Bench.

Index Error =(Observed Distance)—(Actual Distance)

and **Index Correction**=(Actual Distance)—(Observed Distance).

The *index correction* whether positive or negative is always added *algebraically* to the observed distance to get the *correct distance.*

8. Determination of Index Correction. To determine the *Index Correction* for u and v, a *sharp ended straight* knitting needle is used. The knitting needle is adjusted such that its one end touches the pole (P) of the mirror on the reflecting surface. Now the image or the object needle (O) is brought near the other end of the knitting needle and then adjusted in such a way that the tip of the two coincide as shown in Fig. 11.10.

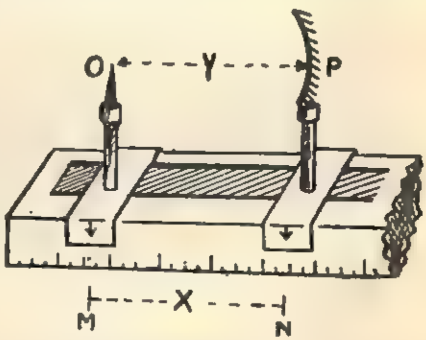


Fig. 11.10. Determination of Bench correction.

Care should be taken not to rotate the uprights or the needles while shifting or adjusting, otherwise index error will change. Note the distance x between the *indices M, N* of the two uprights. The distance x is the *observed distance.* Measure the length of the knitting needle which is equal to the *actual distance y.* If the mounting of the uprights is not disturbed, the index corrections determined for u and v remain constant for all the readings. Thus

Index Correction$=(PO-MN)=(y-x)$.

This index correction is added *algebraically* to the observed distance.

Example :

Suppose the actual length of the knitting needle $=20{\cdot}1$ cm.
Observed corresponding distance for the object upright $=19{\cdot}9$ cm.
Observed corresponding distance for the image upright $=20{\cdot}4$ cm.

Index Correction for $u=20{\cdot}1-19{\cdot}9=+0{\cdot}2$ cm.

and Index Correction for $v=20{\cdot}1-20{\cdot}4=-0{\cdot}3$ cm.

If the *observed distance* for u and v are 40 cm. and 50 cm. respectively then,

the *correct* $u = 40 + 0{\cdot}2 = 40{\cdot}2$ cm.

and the *correct* $v = 40 - 0{\cdot}3 = 39{\cdot}7$ cm.

§ 11·08. Pupil's Experiment No. 1.

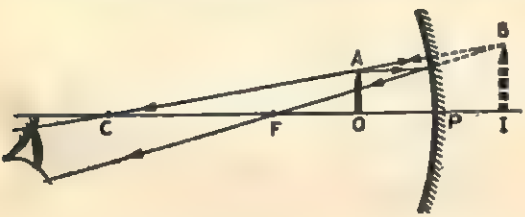
Aim. (*a*) Recording of observations about the nature and composition of images formed by a *concave mirror* as the object distance changes.

(*b*) To determine the relationship between u, v and f.

Apparatus.* An optical bench with three uprights, concave mirror, two needles, a knitting needle, a metre scale and a clamp to hold the mirror on the upright.

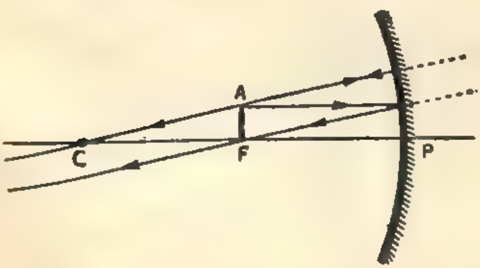
Procedure. (*i*) *Rough focal length 'f'*. Get a clear image of some *distant object* like a tree on a paper screen with the help of the mirror. The distance between mirror and paper screen is equal to the *approximate* focal length '*f*'.

(*ii*) Hold the mirror in the clamp on one upright such that its axis is horizontal. The mirror upright should be near one end of the bench. Look into the mirror by keeping your eye vertically above the bed of the optical bench and rotate the mirror such that you get an image of your eye along the centre of the mirror. This ensures the *principal axis* being along the length of the bench.



Object between F and P.

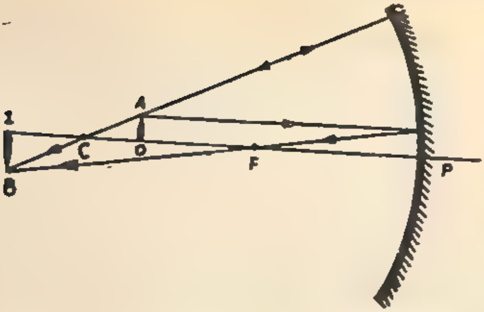
(*a*) The image is
(*i*) Behind the mirror.
(*ii*) Virtual.
(*iii*) Erect.
(*iv*) Larger than object.



Object at F

(*b*) The image is formed at infinity.

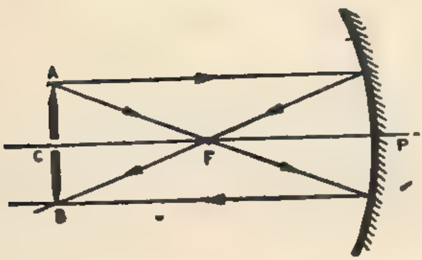
* This experiment can also be done by candle and screen method.



Object between F and C.

(*c*) The image is

(*i*) Beyond C.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Larger than object.



Object at C.

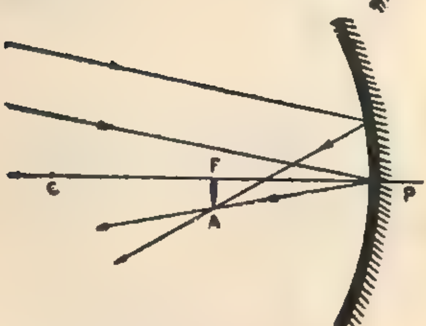
(*d*) The image is

(*i*) At C.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Same size as object.

Object beyond C.

(*e*) The image is

(*i*) Between C and F.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Smaller than object.



Object at Infinity.

(*f*) The image is

(*i*) At F.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Smaller than object.

Fig. 11.12. Formation of image by concave mirror for different positions of the object.

3. Place one upright with a needle on it, so that the tip of the needle and the pole of the mirror are at the same horizontal level. Put this upright at a distance of about '2*f*' from the mirror. You should get an inverted image of the needle. Remove parallax between the needle and its own image as explained in § 11.07. This position of "no-parallax" is the *centre of curvature* 'C' of the mirror as shown in Fig. 11.11 (*d*). The focus 'F' is approximately at a distance of '*f*' from the pole *P* of the mirror.

4. Mount the second upright containing the needle on the optical bench, on the same side of the mirror. Keep the position of the object needle O away from the centre of curvature C as shown in Fig. 11.11(*e*) and remove parallax between its image and the second needle I, called the image needle. Note the position of the *indices* of the three uprights on the bench scale and then find '*u*' and *v*.

5. Place the object needle O at different positions, as shown in Fig. 11.11 (*a, b, c, f*) and trace the corresponding positions of the image by removing the parallax.

The *nature* and *composition* of image formed for different positions of the object needle is mentioned along with the Fig. 11.11.

6. Determine the *index correction* for the object and the image distances.

Observations :

(*i*) Rough focal length of the concave mirrror = ...cm.

(*ii*) *For Index Correction :*—

Length of the knitting needle $=y=$ ......cm.

Observed distance between the mirror and the object needle O $=x=$ ......cm.

Observed distance between the mirror and the image needle I $=z=$ ......cm.

∴ Index correction for u *i.e.*, $(y-x)$ = ...cm.

and index correction for v *i.e.*, $(y-z)$ = ...cm.

(*iii*) Table for u and v.

Set of Obs.	Position of			Observed		Corrected		Inverse of the corrected u and v		
	Mirror P (cm).	Objec needle O (cm).	Image needle I cm.	u (OP) cm.	v (OI) cm.	u cm.	v cm.	$1/u$ cm^{-1}	$1/v$ cm^{-1}	$1/u+1/v$
1.	......	∞	......	∞	f*	∞	f	0	$1/f$	$1/f$
2.	......	......	......	...	...	...	...	...	...	...
3.	......	......	......	...	...	...	...	...	...	...
4.	......	......	......	...	...	...	...	...	...	...
5.	......	......	∞	...	...	f*	∞	$1/f$	0	$1/f$
6.	......	......	......	...	...	...	...	...	...	...

*See the footnote on page 98.

Calculations. (*i*) Mean value of $\frac{1}{u}+\frac{1}{v}$ from observation No. (2), (3) (4) and (6) $= \ldots\ldots cm^{-1}$

(*ii*) Mean value of $\frac{1}{f}$ from observation (1) and (5) $= \ldots\ldots cm^{-1}$

Thus mean of $\frac{1}{u}+\frac{1}{v}$ = mean of $\frac{1}{f}$.

Result. (A) Nature and composition of the image formed :—

(*i*) With the help of a concave mirror the image formed is always **Real** except for the position of the object between the focus and the mirror. For this particular position a magnified **virtual** image is formed.

(*ii*) As the *object approaches* the mirror, the *image moves away* from the mirror and *vice versa.*

(*iii*) The more detailed account regarding the magnification and nature of the image may be referred to Fig. 11.19 (*a*) to (*f*).

(B) The relation between u, v, and f is

$$\boxed{\frac{1}{u}+\frac{1}{v}=\frac{1}{f}}$$

The relation is true for all positions of the object needle.

Precautions. (1) The principal axis of the mirror should be horizontal and parallel to the length of the scale.

(2) The tips of the needles should be on the horizontal plane passing through the *pole* P of the mirror.

(3) The uprights should be rigid and vertical when the bed is levelled.

(4) Parallax between the image and the image needle should be removed tip to tip.

(5) Object and image needles should not be changed or interchanged for different sets of the observations. (Explain with reference to the index correction.) Also the needles should not be rotated.

(6) A piece of chalk may be rubbed to the tip of the object needle so as to get a distinct image.

* The values of v and u for observations 1 and 5 are respectively equal to the focal length f of the mirror by *definition.*

4. REFRACTION THROUGH GLASS SLAB

§11.09. Points to remember

(1) When a ray of light travelling in one medium comes across the surface of another medium in an oblique way, the direction of its path in the second medium is changed, as shown in the Fig. 11.12 according to two laws, known as the **Laws of Refraction.** These are :

First Law. The incident ray, the refracted ray and the normal to the surface of separation at the point of incidence, all the three, lie in one plane.

Second Law. The ratio of sine of angle of incidence to the sine of the angle of refraction is constant for the two media and this constant is called the *Refractive Index* of the second medium with respect to the first medium. Mathematically,

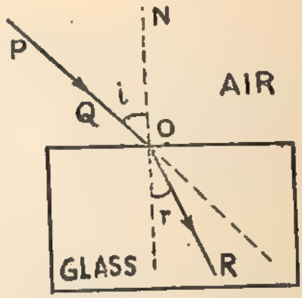


Fig. 11.12. Refraction from air to glass.

$$\frac{\text{Sin } i}{\text{Sin } r}=\mu=\text{Refractive Index.}$$

Here i is angle of incidence and r is angle of refraction.

This law, $\left(i.e., \frac{\text{Sin } i}{\text{Sin } r}=\mu\right)$ is known as **Snell's law.**

(2) Arising out of the two **laws of Refraction,** there are few points which are always helpful to remember.

(i) The incident and refracted rays lie on either side of the normal at the point of incidence.

(ii) A ray of light passing from a *rarer medium* to a *denser medium* bends *towards* the normal. Thus $i > r$.

(iii) A ray of light passing from a *denser medium* to a *rarer medium* bends *away* from the normal. Thus $i < r$.

§11.10. Pupil's Experiment No. 2.

Aim. To trace the path of rays through a glass slab, recording how angle of refraction changes with the angle of incidence.

Apparatus. A glass slab, drawing pins, sheet of paper, drawing board, pins, protractor, half-metre scale.

Theory. Angle of refraction changes with the changes in the angle of incidence according to the **laws of Refraction,** such that

$$\frac{\text{Sin } i}{\text{Sin } r}=\mu=\text{Refractive Index, as explained}$$

in §11.09.

Procedure. (1) Fix the paper sheet on the drawing board and then place the glass slab on it. Mark the boundary *ABCD* of the slab on the sheet with a sharp pencil as shown in Fig. 11.13.

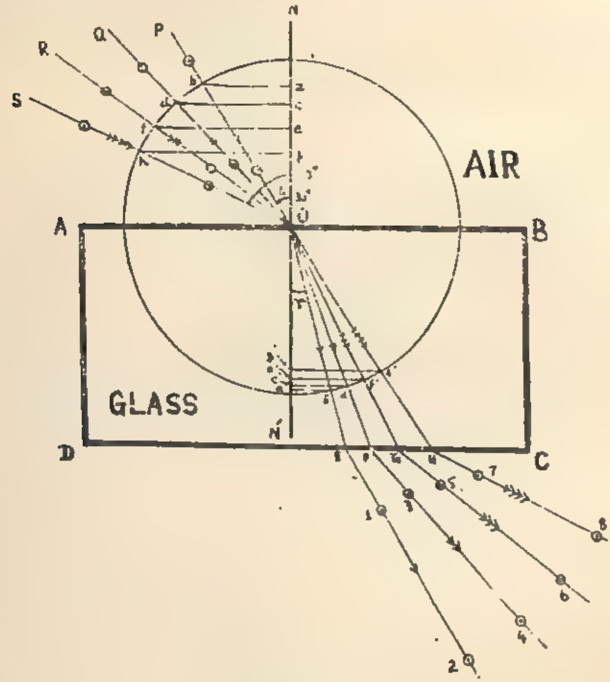


Fig. 11.13.

(2) Remove the glass slab and mark a point *O* nearly at the middle of the line *AB*. Draw the perpendicular *ON* on the line *AB* and also draw lines *OP*, *OQ*, *OR* and *OS* making angles of 30°, 40°, 50° and 60° respectively with the normal *ON* with a protractor.

(3) Now place the slab again in the position *ABCD*. Fix two pins *vertically about 10 cm. apart,* on the line *PO*.

Look through the glass slab along the plane of the paper from the side *CD* and move your head until the images of two pins are seen. Using only one eye, adjust the position of your head such that the two images of the *pins* are in the same straight line. Fix other two pins, *vertically* as marked 1 and 2 in the Fig. 11.13 such that all the four pins appear to be along the same straight line. Remove the pins 1 and 2 and mark their positions by encircling the pin points on the paper sheet.

The experiment is repeated by fixing the needles on the lines *OQ*, *OR* and *OS* also. Let the lines joining the position of the needles 1, 2 ; 3, 4 ; 5, 6 and 7, 8 meet the line *CD* at the points *E*, *F*, *G* and *H* respectively.

(4) Remove the slab and join OE, OF, OG and OH. Thus for the incident rays PO, QO, RO and SO we get the refracted rays as OE, OF, OG and OH respectively.

Measure the angles of refraction EON', FON', GON' and HON'.

(5) With the help of the *sine table* see the Sin i and Sin r for all sets of observations.

(6) In case sine tables are not available, the value of Sin i/Sin r is calculated as follows.

Draw a circle of suitable radius taking the point O as centre and draw perpendiculars on the normal NN' from those points at which the incident rays and refracted rays meet the circumference of this circle (as shown in the Fig. 11.13). The lengths of these perpendiculars drawn are measured. Now, $\frac{\sin i}{\sin r}$ for the case in which PO and OE are the incident and the refracted rays respectively, is given below

$$=\frac{\text{Sin } i}{\text{Sin } r}=\frac{ab/ob}{a'b'/ob'}=\frac{ab}{a'b'}\times\frac{ob'}{ob}$$

or $\qquad \mu=\frac{ab}{a'b'}$ since $ob=ob'$ (radii of the same circle)

Similarly the value of μ from other observations can be calculated.

Observations

S.N.	*Angle of Incidence (i)*	*Angle of Refraction (r)*	*Sin i*	*Sin r*	*Sin i/Sin r*
1.	30°				
2.	40°				
3.	50°				
4.	60°				

$$\mu=\text{mean } \frac{\text{Sin } i}{\text{Sin } r}=\ldots\ldots$$

Result. Angle of refraction (r) *increases* with the *increase* in the angle of incidence (i) such that sin i/sin r is a constant and is equal to ...for air and glass.

Precautions

(1) The boundary of the glass slab on the paper sheet should be marked with a *sharp* pencil.

(2) Pins should be fixed *vertically* and minimum distance between two pins on the same line should be more than about 8 *cm*.

(3) The feet of the pins should lie in the same straight line.

(4) Encircle the pin-pricks, *immediately after* removing them.

(5) The angle of incidence should lie between 30° and 70°.

5. PATH OF RAYS THROUGH A PRISM

§11.11. Points to remember.

(1) Read the text under the heading "Points to remember" of §11.01.

(2) Fig. 11.14 represents the course of a ray *EFGH* through a glass prism whose principal section is *ABC*. *EF*, *FG* and *GH* are the *incident*, the *refracted* and *the emergent* rays respectively. *FN* and *GN* are the normals to the faces *AB* and *AC* respectively. The angle *i* and *e* are the angle of *incidence* and the angle of *emergence* respectively. The angle *D* between the incident ray, *EFT*, and the emergent ray, *PGH*, is called the *angle of deviation.* If the angle *BAC* of the prism be represented by *A*, then

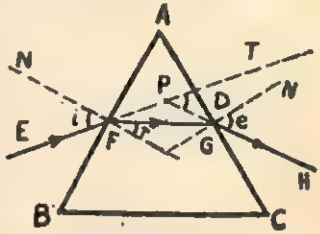


Fig. 11.14. Refraction through a prism.

$$\boxed{A+D=i+e}$$

§11.12. Pupil's Experiment No. 3.

Aim. To trace the path of rays through a given prism.

Apparatus. Drawing board, sheet of paper, glass prism, pins, half-metre scale, graph paper and protractor.

Theory. As discussed in the point (2) of §11.11.

Procedure. (1) Fix the sheet of paper on the drawing board and draw a line *XY* nearly in the centre of the paper and along its length. Draw the normals to the line *XY* at points *O* at suitable spacings and then the lines corresponding to the *incident* rays are drawn at angles of incidence ranging from 30° to 60° at intervals of 5° as shown in Fig. 11.15 with the protractor.

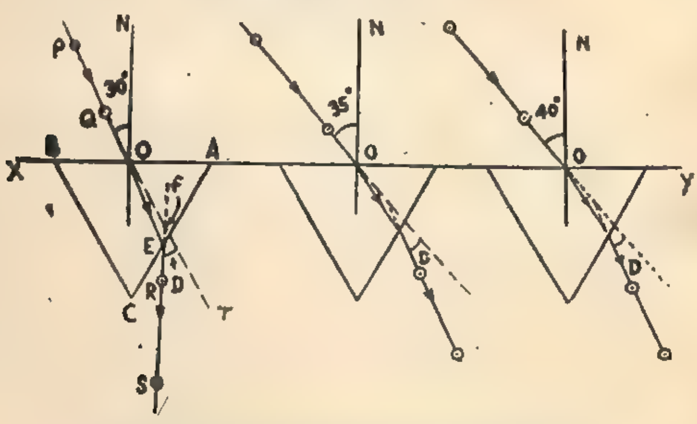


Fig. 11.15. Tracing the path of rays through a prism.

(*ii*) The prism is placed with one of its refracting surfaces on the line *XY* and its boundary *ABC* is traced as shown in the Fig. Two pins *P* and *Q* are now fixed on the *incident ray* line and its image is viewed with the eye from the side *AC* of the prism. Fix two pins *R* and *S* on the paper such that the tips of these pins, and the images of the incident ray pins, all lie on the same straight line. Remove the pins *R* and *S* and *encircle* the pin-pricks. Join *SR* and produce it back to meet the face *AC* at *E* and *PQ* produced at *F*. Join *OE* and thus if *PQ* is the *incident* ray, then *OE* and *RS* are the *refracted* and the *emergent* rays respectively. Draw arrow-heads to indicate the direction of travel of these rays. Measure the angle *SFT* which is the *angle of deviation D*.

(*iii*) Repeat the experiment for different values of the angle of incidence and finally measure the corresponding angles of deviation *D*. Record the observations as shown below.

Observations. Table for angles *i* and *D*.

No. of observation	*Angle of incidence i (in degrees)*	*Angle of Deviation D (in degrees)*
1.	30	
2.	35	
3.	40	
4.	45	
5.	50	
6.	55	
7.	60	

Graph. Plot a graph by taking angle of incidence *i* along *X*-axis and angle of deviation *D* along *Y*-axis as shown in Fig. 11.16.

Result. When a ray passes through a prism then angle of deviation *decreases* for the *increase* of angle of incidence and attains a minimum value. But if the angle of incidence is increased beyond this value, the angle of deviation starts increasing again.

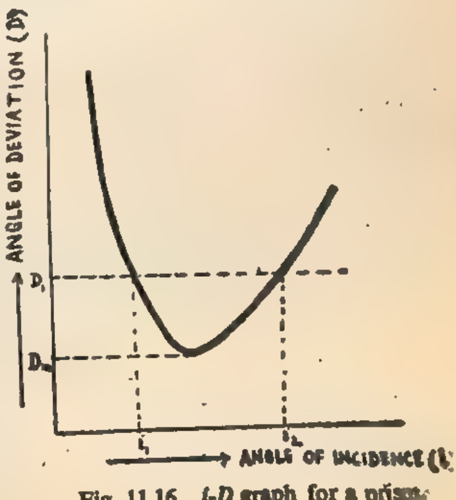


Fig. 11.16. *i-D* graph for a prism.

Thus there is a particular value of the angle of incidence for which the angle of deviation is minimum D_m. It is called the angle of **minimum deviation.** As shown in the Fig. 11.16, a line parallel to *i*-axis cuts the graph at two points. It means that one angle of deviation can be obtained for two angles of incidence. However, for the

lowest point of the curve, there is only one angle of incidence.

Precautions

(1) The boundary of the prism should be drawn with a sharp pencil.

(2) The point of incidence should be in the middle portion of the prism.

(3) The angle of incidence should be between 25° and 60°.

(4) The same angle of the prism should be used for all the observations and therefore it should be marked with ink before the start of experiment.

(5) The pins *P* and *Q* should be well illuminated and all the pins should be fixed *vertically* such that their tips in contact with the paper are in the same line.

(6) Encircle the pin-pricks *immediately after* removing them.

6. CONVEX LENS

§11.13. Points to Remember

(1) **Convex Lens.** A convex lens is a transparent medium bounded between *two curved surfaces or one curved surface and the other plane surface* such that it is thicker at the central part than at the edges. The line passing through the centres of curvature of the two surfaces is called the **Principal Axis.** These lenses are also called **Convergent Lenses** because they converge the rays of light falling on them.

(2) **Definitions**

Optical Centre. It is a fixed point in a convex lens and has the property that the rays passing through it do not suffer any deviation due to lens. Thus the incident and emergent rays are parallel.

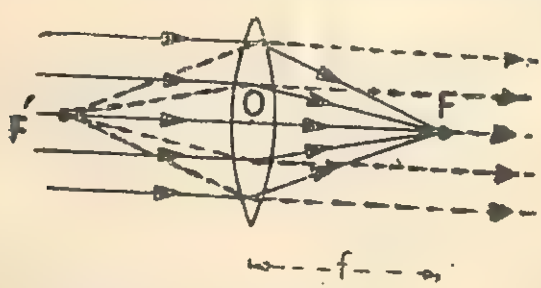


Fig. 11.17. Principal Focii of a convex lens.

Principal Focus. When a parallel beam of light, parallel to the *principal axis*, passes through a convex lens, it converges at a point F on the principal axis on the other side of the lens as shown in Fig. 11.17. This point F is called the **First Principal Focus.** The distance between the optical centre O and the first *principal focus F* is called the **First Principal focal length** or simply the **Focal Length.** There is another point F' at the same distance (equal to focal length) from O on the other side of the lens which is called the second **principal focus.** The property of the point F' is that rays starting from this point are rendered parallel after passing through the lens as shown in Fig. 11.17.

(3) The object distance u, image distance v and the focal length f are related by the formula $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$.

(4) **Sign Conventions.** (*i*) Incident rays are taken from the left towards right on the lens. (See Fig. 11.18.

(*ii*) All the distances are measured from the *optical centre* as origin along principal axis.

(*iii*) Distances measured **in the direction** of the incident rays are taken **positive.**

(*iv*) Distances measured **opposite to the direction** of the incident rays are taken **negative.**

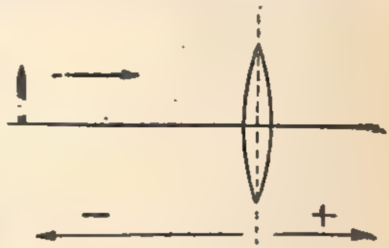


Fig. 11.18. Cartesian sign conventions for u, v and f.

(5) For *optical bench, Index correction* and *parallax* read §11.07.

§11.14. Pupil's Experment No. 4.

Aim. (*i*) Recording the observations about nature and position of the image as the object distance is changed. (*ii*) To determine the relationship between u, v and f.

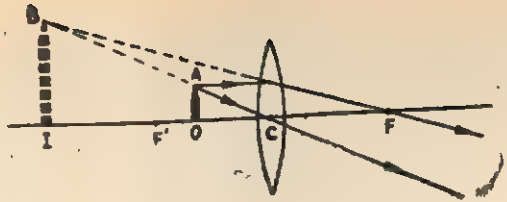
Apparatus*. A convex lens of short focal length, two needles, three uprights, one clamp, an optical bench, a half-metre scale and a knitting needle.

Theory. If a needle be placed beyond the focus of a convex lens, its real inverted image is formed on the other side of the lens. The position of the image may be located with the help of another needle by removing parallax** between the tips of the image and the second needle. If u, and v are the object and the image distances respectively, the focal length of the lens is given by the relation,

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}.$$

Sign convention must be followed while putting the values of u and v in this formula.

*The experiment can also be done by candle and screen method.
**Read § 11.07, point 5.

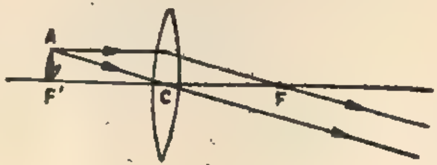


(a)

Object between Lens and F′.

The image is,

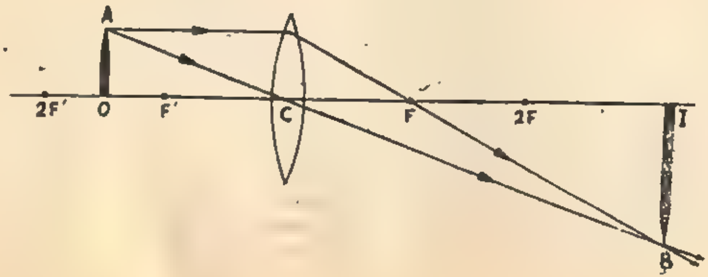
(i) Behind the object.
(ii) Virtual.
(iii) Erect.
(iv) Larger than the object.



(b)

Object at F′.

The image is at infinity.

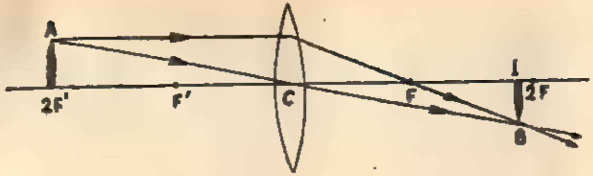


(c)

Object between F′ and 2F′.

The image is,

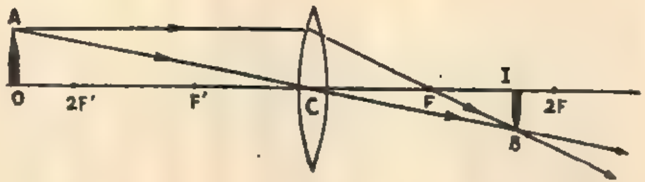
(i) Beyond 2F.
(ii) Real.
(iii) Inverted.
(iv) Larger than the object.



(*d*) **Object at 2F′.**

The image is,

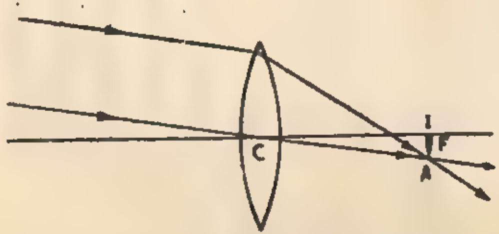
(*i*) At 2F.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Same size as object.



(*e*) **Object Beyond 2F′.**

The image is,

(*i*) Between F and 2F.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Smaller than object.



(*f*) **Object at Infinity.**

The image is,

(*i*) At F.
(*ii*) Real.
(*iii*) Inverted.
(*iv*) Smaller than object.

Fig. 11.19. Formation of image by a convex lens for different positions of the object *OA*.

Procedure. (1) Determine the focal length of the lens *approximately* by focusing a *sharp, clear* and *inverted* image of a distant object on a white paper. Let this focal length be f.

(2) Mount the lens in the clamp. Mount the clamp with lens on the central upright of an optical bench and the two needles on the remaining two uprights. Arrange the tips of the needles at the same vertical height as the centre of the lens. The **Principal Axis** of the lens should be parallel to the scale. Mark one of the needles as the object needle and the other as the image needle.

(3) Determine the *index corrections** to be applied to u and v with the help of the knitting needle and the half-metre scale.

(4) Arrange the position of the object needle O at a distance greater than $2f$ from the lens as shown in Fig. 11.19(e). Look from the other side of the lens along its principal axis near the end of the bench. If the setting is correct, an *inverted real* image I is seen. Now adjust the position of the second needle such that parallax** between the image and the image needle is removed. Vertical position of the second needle is adjusted such that parallax is removed tip to tip of the image and the needle.

Note the positions of the *indices* of the uprights carrying the needles and the lens and thus find the *observed* u and v. Apply *index corrections* to get correct u and v.

(5) Repeat the observations for different positions of the object needle with respect to the lens as shown in Fig. 11.19 (d, c, b, a, f). Observe the nature and size of the image in each case.

Observations

(i) Approximate focal length of the lens $(f)=$...cm.

(ii) For Index Correction.

Actual length of the knitting needle $(y)=$...cm.

Observed corresponding distance between the object needle and the lens $(x)=$...cm.

Observed corresponding distance between the image needle and the lens $(z)=$...cm.

$\therefore$ Index Correction for u, $(y-x)=$...cm.

and Index Correction for v, $(y-z)=$...cm.

* read § 11.07 point 8.

** read § 11.07 point 5.

(*iii*) **Table for u and v.**

Sets of obs.	Position of			Observed		Corrected		$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{u}+\frac{1}{v}$
	Object needle (cm)	Image needle (cm)	Lens (cm)	u (cm)	v (cm)	u (cm)	v (cm)			
1.	∞	...	...	∞	v	∞	f	0	$1/f$	$1/f$
2.	...	.	...	...	...	...	...		...	...
3.	...	...	...	...	...	...	...	...	...	...
4.	...	...	...	...	...	...	...	...	...	...
5.	...	∞	...	...	∞	f	∞	$\frac{1}{f}$	0	$1/f$
6.	...	...	...	...	...	...	...	...	...	...

Mean $\frac{1}{u}+\frac{1}{v}=$...... (from observations 2, 3, 4 and 6).

Mean $\frac{1}{f}=$......from observations 1 and 5.

It is seen from the last column of the observation table that for all the readings

$$\frac{1}{u}+\frac{1}{v}=\text{constant} \qquad ...(1)$$

To find out the value of this constant let us consider the special cases regarding

$$\frac{1}{u}+\frac{1}{v}.$$

Case I. When the object is at infinity, *i.e.* $u=\infty$ in that case equation (1) gives

$$\frac{1}{\infty}+\frac{1}{v}=\text{constant}=k \text{ (say)}$$

$$\therefore \qquad v=\frac{1}{k}.$$

But according to the definition of first principal focus F (See point 2 of §11.13), in this case, v is nothing but first **Principal Focal Length** (f) because when the object is situated at infinity then rays falling on lens are parallel. Hence

$$v=f=\frac{1}{k}$$

$$\text{or} \qquad k=1/f \qquad ...(2)$$

Case II. When the image is formed at infinity *i.e.* $v=\infty$

Putting $v=\infty$ in equation (1), we get

$$\frac{1}{u}+\frac{1}{\infty}=\text{constant}=k$$

$$\therefore \qquad \frac{1}{u}=k \qquad \text{or} \qquad u=\frac{1}{k}.$$

But according to the definition of the second principal focus F' (see point 2 of §11.13), in this case, u is nothing but second principal focal length (f).

Therefore in this case,

$$u=f=\frac{1}{k} \qquad \text{Hence} \qquad k=\frac{1}{f} \qquad ...(3)$$

Thus from equations (1), (2) and (3), we conclude that for a convex lens

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \qquad ...(4)$$

Result. (A) **Nature** and **composition** of the image for different positions of the object with respect to the **Convex Lens** is illustrated along with the Fig. 11.19. (*a*) to (*f*).

(*i*) When the object position is at a distance greater than f, always a **real** inverted image is formed. The image moves away from the lens as the object approaches the point F.

(*ii*) When the object is placed at the focus F, the image is formed at infinity or the emergent rays are rendered parallel.

(*iii*) When the position of the object is between F and the lens, a **virtual** *erect* and *magnified* image is formed.

(B) The relation between u, v and f for a convex lens is established to be

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}.$$

Precautions. (1) Tips of the needle should be as high as the optical centre of the lens.

(2) The upright should not be shaky. It should be vertical.

(3) The principal axis of the lens should be parallel to the scale.

(4) The parallax should be removed tip to tip.

(5) Place your eye away from end of the bench so that the distance between the image needle and the eye is more than 25 cm.

(6) Chalk piece may be rubbed on the tip of the object needle to make the image shining.

(7) Index corrections should be determined carefully. For this purpose the position of the object and the image needles should neither be interchanged nor rotated.

7. TELESCOPES AND MICROSCOPES

§11.15. Telescope

It is an instrument used for seeing the details of far off objects as they are not clearly visible to the naked eye. Telescopes may be put into two categories :

(*i*) Refracting Telescopes and (*ii*) Reflecting Telescopes.

Further there are many types of telescopes in both the categories. We shall discuss here only the Astronomical Telescope which is a refracting type of telescope.

§11.16. Group Activity No. 1.

Aim. To prepare a model of an astronomical telescope.

Apparatus. Two lenses of focal lengths say 30 cm. and 5 cm. Two tubes T_1 and T_2 (card-board tube, bamboo tube or suitable metal tube) of lengths 40 cm. and 8 cm. respectively, suitable tools for fixing the lenses in the tubes.

The internal diameters of the tubes should be slightly smaller than the sizes (diameter) of the lenses to be fixed. The external diameter of T_2 should be such that it can slide in the tube T_1.

Theory. The front lens of a telescope which points towards the object is called *Objective*. The purpose of objective is to collect light from the distant object and to form a real image of it in front of the second lens, which is called the *Eye Piece* because it is near the eye of the observer as shown in Fig. 11.20. If F and f are the focal lengths of the *objective* and the *eye-piece* respectively, then the distance between the two lenses is $(F+f)$. For this separation of the two lenses telescope is said to be in the *normal adjustments*. The objective L_1 forms the real image of the distant object at the common focal plane of the two lenses. This image acts like the object for the *eye-piece* and thus the final image is formed at *infinity*. Of course, the parallel rays emergent out of the *eye-piece* are focused by the eye at its retina. For the normal adjustment, the eye sees the image in a *relaxed* manner. The magnifying power of the telescope under normal adjustments is equal to (F/f).

Procedure

(1) Fix the objective lens L_1 (30 cm. focal length) at one end of the tube T_1 and the eye-piece L_2 (5 cm. focal length) at one end of the other tube T_2 as shown in Fig. 11.20.

(2) Slide the tube T_2 into the tube T_1 as shown. Provision should be made such that the tube T_2 does not come out of the tube T_1 automatically. Now this telescope can be used to observe distant objects as discussed below.

(3) Point the telescope towards a distant object such that its objective L_1 is towards the object and the eye-piece L_2 is close to the eye of the observer. Now adjust the position of the eye piece by sliding the tube T_2 to get a distinct and inverted image of the distant object.

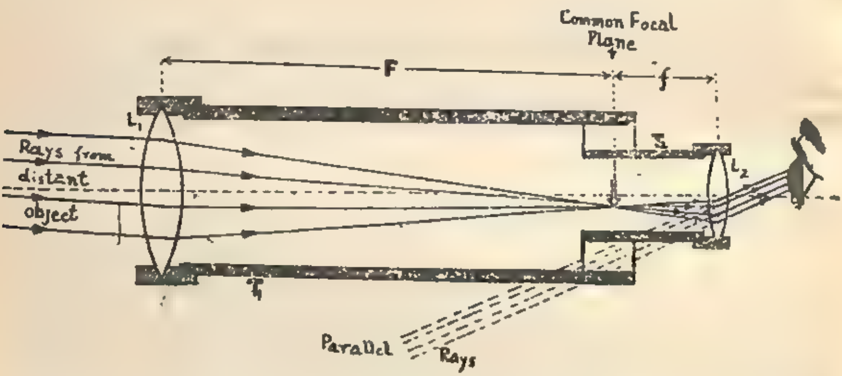


Fig. 11.20. Course of rays coming from a distant object through a telescope.

Note : Students may apply their own skills also, for the proper fitting of the lenses.

§11.17. The Compound Microscope.

It is an instrument for seeing small objects which are not visible clearly to the naked eye. This instrument consists of two lenses of short focal lengths arranged as shown in Fig. 11.21. The first of these lenses, called the **objective,** produces an enlarged, real, inverted image I_1 of the small object O.

The image I_1 then acts as an object for the eye piece. Now the eye-piece makes a virtual, and enlarged image I_2 of I_1. This image I_2 is seen by the eye.

§11.18. Group Activity No. 2.

Aim. To prepare a model of a compound microscope.

Apparatus. Two lenses of short focal lengths (preferably watch maker's lenses of focal lengths 5 cm. and 20 cm.), three tubes T_1, T_2, T_3, of lengths 4 cm., 30 cm., 10 cm., respectively (the internal and external diameters of these tubes should be such that the arrange-

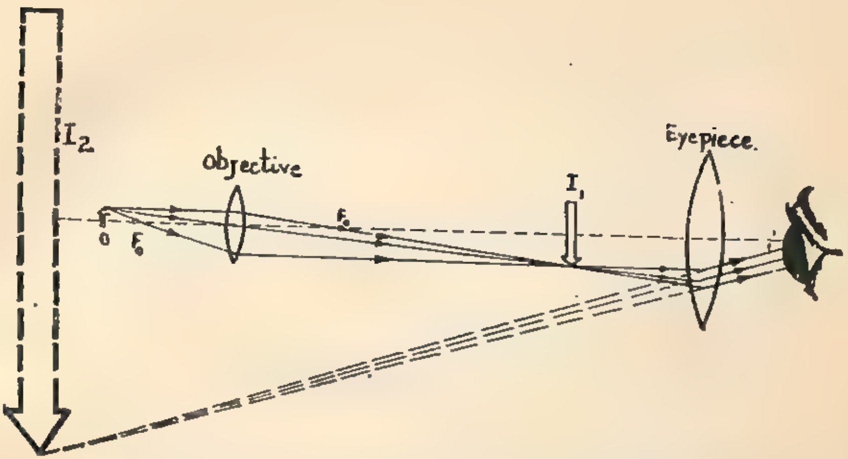


Fig. 11.21. Course of rays through a compound microscope.

ment as shown in Fig. 11.22 can be fitted), wooden ring W, W, for the proper fitting of the objective and proper tools for the fitting.

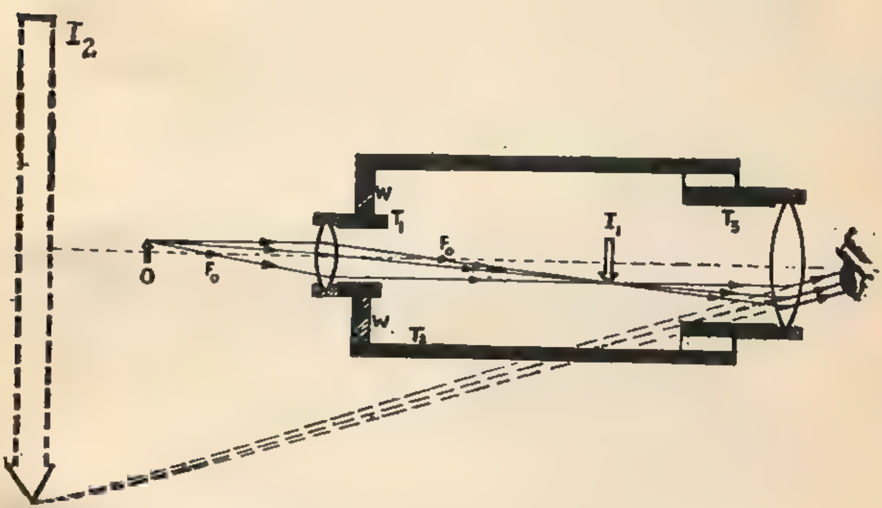


Fig. 11.22. Demonstration model of a compound microscope.

Theory. See §11,17.

Procedure

(*i*) Fix the objective lens (5 cm. focal length) at one end of the tube T_1 and the eye piece (20 cm. focal length) at one end of the tube T_3.

(*ii*) Fix the objective tube assembly, T_1, to one end of the tube T_2 with the help of wooden ring W as shown in Fig. 11.22.

(*iii*) Slide the eye-piece tube T_3 into the other end of the tube T_2 as shown. After adjustments of the tubes, this microscope is ready for observations.

(*iv*) Now point the objective of the microscope towards a small and nearby object, say a fine print of a book, and look through the microscope such that eye is very close to the eye-piece. Adjust the distance of the eye-piece by sliding the tube T_3 to get a distinct image of the object.

Note. Students may use their own skills to fix the lenses properly in suitable tubes.

QUESTIONS

Viva-Voce on lenses, mirrors, etc.

1. What do you mean by a spectrum ?
2. Explain the terms focus, focal length, radius of curvature and pole of a mirror.
3. Under what condition a virtual image is formed with a concave mirror ?
4. Is it possible to have a real image with a convex mirror ?
5. What are the practical applications of curved mirrors ?
6. Define the terms focus, focal length, optical centre and power of a lens
7. Is it possible to get a real image with a concave lens ?
8. How will you judge whether a lens is convex or concave ?
9. Explain the functions of a telescope and a microscope.
10. How will you judge whether a given mirror is plane or concave or convex ?
11. What do you understand by index error and index correction ?
12. What do you understand by removing parallax ?
13. How will you remove parallax between an object and an image ?
14. Can you remove parallax between an object and its virtual image ?
15. Can you determine the focal length of a convex mirror by the method mentioned in § 11·08 ?
16. Can you determine the focal length of a concave lens by the method mentioned in § 11·14.
17. How can a small shop be made to appear spacious ?
18. Why is a concave mirror sometimes used as a shaving glass ?
19. Why a convex mirror, to be used in front of a driver, is preferable over a plane or concave mirror ?
20. Can you see the back of your head with the help of two mirrors ?

12

Electricity and Magnetism

1. ACCESSORIES FOR ELECTRICAL EXPERIMENTS

§12.01.

1. **Source of e.m.f. or cell.** It is the source of electrical current in conductors. The cell maintains a potential difference between its two electrodes by virtue of the chemical reaction going on inside the cell. There are two types of cells.

(*a*) Primary cells and (*b*) Secondary cells.

(*a*) *Primary cells.* These are the cells in which the chemical action going on inside the cell supplies directly the electrical current. These cells do not require charging by a separate source. The primary cells commonly used in the laboratories are :

(*i*) **The Leclanche Cell.** This cell consists of a glass vessel containing a strong solution of ammonium chloride. The *Positive Electrode* is a carbon rod placed inside a porous pot. The space between the porous pot and the carbon rod is filled with manganese dioxide and charcoal powder. The *Negative Electrode* consists of a zinc rod dipped inside the solution. The e.m.f. of the cell is 1·45 volts. A sketch of this cell is shown in Fig. 12.1.

Leclanche cell is used for the intermittent supply of current. Thus it is suitable for electric bell, telephone and telegraph operations. Inside the laboratory, this cell is suitable for experiments like slide wire bridge, post office box.

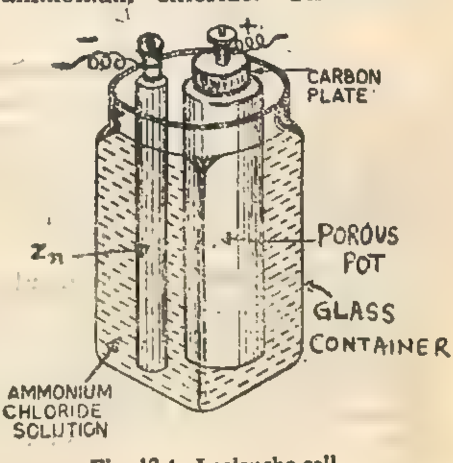


Fig. 12.1. Leclanche cell.

(*ii*) **The Daniel Cell.** This cell consists of a copper vessel containing a saturated solution of copper sulphate. To maintain the

copper sulphate solution saturated, there is provision for keeping the copper sulphate crystals which are dipped in the solution as shown in Fig. 12.2. The copper vessel itself acts as the *Positive Electrode*. A porous pot containing dilute sulphuric acid is dipped inside the copper sulphate solution. A zinc rod dipped in the sulphuric acid solution acts as the *Negative Electrode*. The e.m.f. of the cell is 1·08 volts which remains fairly steady.

(*iii*) **The Dry Cell.** We all are familiar with this cell as it is generally used in torch and transistor radio etc. This cell essentially is a leclanche cell in which the electrolyte is taken in the form of a paste.

(*b*) **Secondary Cells.** These cells are first charged by passing a current through them with the help of a separate source of e.m.f.

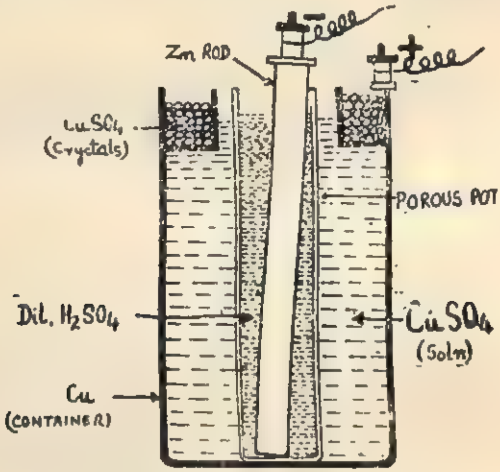


Fig. 12.2. Daniel cell.

(say a charger). Thus energy is *stored* or *accumulated* in these cells by way of the charging process and hence these cells are also called *Storage cells* or *Accumulators*. After the charging, the cell is ready for supplying current. There are two types of accumulators used in the laboratories as discussed below :

(*i*) **The Lead-acid Accumulator.** This cell consists of a glass or plastic vessel containing dilute sulphuric acid of specific gravity 1·21. The positive post or anode consists of a *Grid* of lead. The grooves of the grid contain a paste of lead peroxide. The negative post or cathode is a special preparation of spongy lead. The e.m.f. of this cell is 2 volts. This cell can supply large current continuously for several hours. When the cell is in use, the specific gravity of sulphuric acid decreases and when the sp. gravity falls to 1.18, corresponding to an e.m.f. of 1.8 volts, the cell requires recharging. The sketch of a battery of 6 volts made out of these cells is shown in Fig. 12.3.

(*iii*) **The Alkali Accumulator or Ni Fe cell or Edison cell.** This cell consists of an *aluminium* vessel containing 21% solution of caustic potash in water. The negative plate consists of an iron powder rigidly held in perforated capsules. Nickel peroxide held in perforated cylinders constitutes the positive plate. The e.m.f. of the cell is 1·35 volts. Although the e.m.f. of this cell is not as steady as that of an acid accumulator, but it is very suitable where handling of the cell is rough. The life of the cell is long.

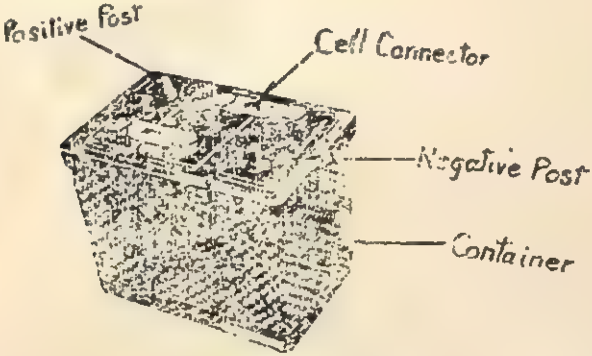
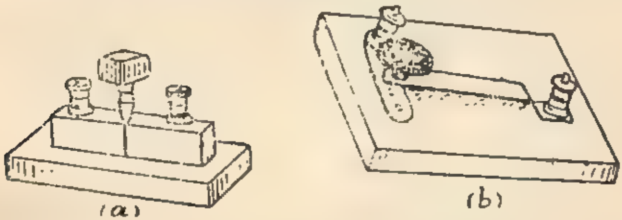


Fig. 12.3. Acid Accumulator.

(2) **Key.** The purpose of a key is to pass the current or to stop the current as desired in a circuit. The common forms of the keys used in the laboratories are shown in Fig. 12·4 *a*) and (*b*). When the current is not required, an air gap is introduced between the two terminals of the key. Fig. 12.4 (*a*) and (*b*) represent a plug key and a tapping key respectively.



(*a*) Plug key (*b*) Tapping key

Fig. 12.4. Keys.

(3) **Rheostat.** It is used to decrease or increase the current in a circuit. It consists of long resistance wire of eureka (constantan) or magnin which is wound over

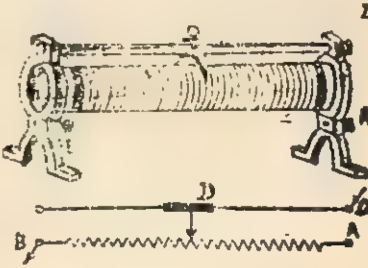


Fig. 12.5. Rheostat.

a non-conducting cylinder as shown in Fig. 12.5. The ends of the wire are connected to the binding terminals *A* and *B*. A rod *D* is attached to the frame such that a slider or jokey can slide on it and also can make contact with the wire windings. The purpose of this construction is to introduce varying amount of resistance in a circuit.

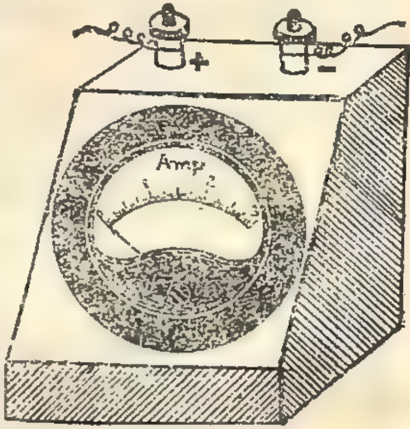


Fig. 12.6. Ammeter.

(4) **Ammeter.** This instrument is used to measure the magnitude of current in a circuit. It has a low resistance. It is always connected in series with the circuit in which the current is to be measured in such a way that the current enters at its positive terminal and comes of the ammeter from its negative terminal Fig. 12.6 represents an ammeter which can measure currents upto 3 amperes.

(5) **Voltmeter.** This instrument is used to measure the potential difference. It is similar to an ammeter but has a very high resistance. It is always connected in parallel to the conductor or

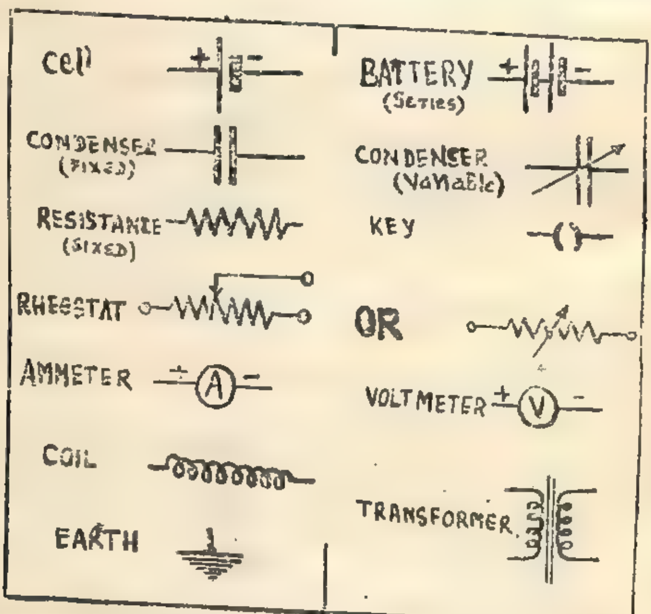


Fig. 12.7. Symbols for electrical components.

the source of e.m.f. whose potential difference is to be measured in such a way that its positive terminal is connected to the positive and negative terminal is connected to the negative of the source.

(6) **Symbols used in Circuit Diagrams.** Fig. 12.7 illustrates the symbols used for different electrical components.

2. INTERACTION BETWEEN CURRENT CARRYING CONDUCTORS

§12.02. Points to remember.

(1) Magnetic field is always associated with an electric current.

(2) **Straight conductor.** The **direction** of the magnetic field produced by a straight conductor carrying current is given by the **Right Hand** grip rule. *Imagine the straight wire to be grasped in the right hand with the thumb pointing along the wire in the direction of the current, i, (conventional)*. The direction of the fingers will give the direction of the magnetic field, H, as shown in* Fig. 12.8. The magnitude of the field produced at a point depends upon the strength of the current flowing, the distance of the point from the conductor, the situation of the point with respect to the ends of the conductor and the medium surrounding the point.

Fig. 12.8. Right hand grip rule.

(3) A conductor carrying current, is acted upon by a force when it is placed in an external magnetic field which is produced by some other source. The direction of the force is given by **Fleming's Left Hand Rule** when the direction of the current and the *external magnetic* field are perpendicular.

Fleming's Left Hand Rule. Stretch the first finger, middle finger and thumb of the left hand (as shown in Fig. 12.9. If the first finger points in the direction of the magnetic field, the middle finger points in the direction of the current, then, the thumb will point in the direction of the force on the conductor carrying the current. Hence the conductor will move in the direction in which the thumb points out! This rule for getting the direction of motion of conductor carrying current placed in perpendicular magnetic field is known as F.L.H. rule.

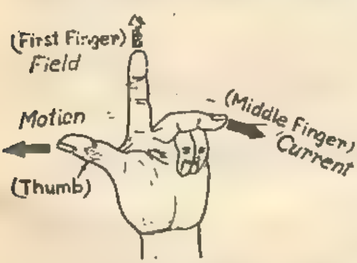


Fig. 12.9. Fleming's Left Hand Rule.

* The *conventional* direction of electric current is opposite to the direction of electron flow. Thus the conventional current flows from *positive* towards negative due to a cell in the external circuit.

(4) When there are two current carrying conductors placed closeby, not necessarily parallel as shown in Fig. 12.10, there will be attraction or repulsion between them depending upon the relative directions of the currents as discussed below :

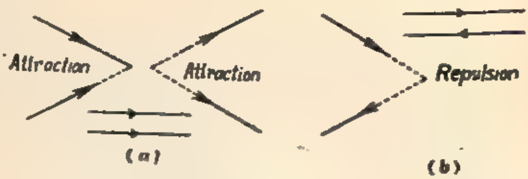


Fig. 12.10. Action of current on current.

(i) There will be **attraction** if the direction of the two currents are either the **same** or they appear to **converge** to or **diverge** from, a point as shown in Fig. 12.10 (a).

(ii) There will be repulsion if the directions of the two currents are opposite as shown in Fig. 12.10(b).

(5) **Unit of electric current : The Ampere.** One ampere is the current which, if flowing in two straight wires of infinite length placed 1 metre apart in vacuum, will exert on each of the wires a force of 2×10^{-7} newton per metres length of the wire.

(6) **Quantity of Electricity : The Coulomb.** A coulomb is the quantity of electricity which passes any point in a circuit in 1 second when a steady current of 1 ampere is flowing.

(7) **Unit of Potential Difference : The volt.** Two points are said to be at a potential difference of 1 volt if 1 joule of work is done when 1 coulomb of electricity passes from one point to another.

(8) **Electromotive force or E.M.F. of a cell.** The e.m.f. of a cell (in volts) is defined as the total work done in joules per coulomb of electricity conveyed in a circuit in which the cell is connected.

§12.03. Demonstration Experiment No. 5

Aim. To demonstrate the interaction between two wires carrying current.

Apparatus. Thick copper wire, mercury in a metal dish, a tapping key, a battery of 2 to 4 volts, two metallic hooks, a wooden stand and a rheostat.

Procedure. (A) (i) Arrange the circuit connections as shown in Fig. 12.11 (a).

(ii) Note the spacing of the parallel copper wires *AB* and *CD*.

(iii) Now pass a suitable current by pressing the tapping key (T.K.) as shown in Fig. 12.11 (b) and note that the *spacing decreases*. The maximum decrease is at the ends in contact with mercury. In this case *the currents in the two wires are in the* **same** *direction and they attract each other.*

(iv) Increase the current further by decreasing the resistance

with the help of the rheostat and note that the spacing further decreases.

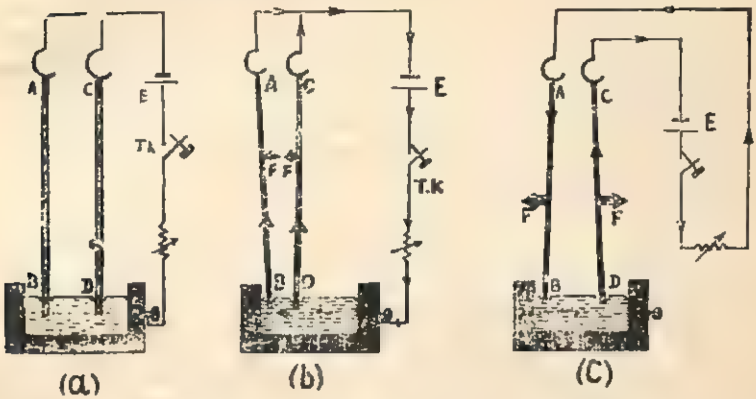


Fig. 12.11. Action of current on current.

(*B*) (*i*) Now arrange the circuit connections as shown in Fig. 12.11 (*c*).

(*ii*) Pass the current by pressing the tapping key and note that the spacing between the wires increases, the maximum separation between the wires being at the ends in contact with mercury. Thus *for the currents in* **opposite** *directions there is a force of repulsion between the wires.*

Conclusion. (*A*) Two parallel wires attract each other if they have currents in the same direction.

(*B*) Two parallel wires repel each other if they have currents in opposite directions.

3. V, I (VOLTAGE, CURRENT) Characteristics

§12.04. Points to remember.

(1) **Current.** Electrical current is the *flow* of charged particles. In the case of current through metals and other solid conductors it is due to the flow of **electrons**. The *direction* of current, also called *conventional current is opposite* to the direction of flow of electrons.

(2) On the basis of their capacity to conduct electricity, matters are divided into three categories : **Conductors, Semi-conductors** and **Insulators**.

Conductors. The materials inside which large number of *free electrons* are available to conduct electricity are called conductors. In metals such free electrons, are available in abundance and metals are therefore, good conductors.

Semi-conductors. These are the materials in which *very few* electrons, are available to conduct electricity.. Silicon and Germanium are popular examples of such materials.

Insulators. These are material in which no free electrons are available to conduct electricity. Mica, dry wood, etc. are the examples of Insulators (bad conductors) of electricity.

(3) **Ohm's Law** states that the *current passing through a conductor is directly proportional to potential difference between its ends provided the physical conditions* (*i.e.* temperature etc.) *remain the same.* remain the same. Mathematically,

$$V \propto I$$

or

$$V = IR$$

where V and I are the potential difference and the current respectively. R is a constant, called the resistance of the metal or wire. Resistance depends upons the *dimensions* of the conductor and nature of its material. The SI unit of resistance is **ohm**. *The tendency* of resistance is to offer *obstruction* or *hindrance* to the flow of current.

Ohm's Law holds good for **conductors** and semi-conductors. **Ohm's Law is not** valid for the **vacuum tubes** like diodes and triodes and for the conduction through gases.

(4) **The ohm.** One ohm is the resistance of a conductor across the ends of which a potential difference of one volt is developed when a current of one ampere passes through it.

§12.05. Pupil's Experiment No. 5(*a*).

Aim. To study the variation of current with the potential difference applied (*i.e.* V, I characteristics) across a *conductor.*

Apparatus. A D.C. voltmeter (0.5 volts), eureka (constantan) wire of about 1 metre length streched between two terminals on a non-conducting board, an ammeter (0—1·5 amps) a rheostat (10 ohms).

Procedure

(1) Arrange the apparatus on the working table in the laboratory and assemble the circuit connection as shown in Fig. 12.12. AB represents the experimental wire or coil. The ammeter is connected in series with the wire AB and the voltmeter is connected in parallel *i.e.* across AB. Note the zero errors of the ammeter and voltmeter, if any.

(2) Insert the plug key K and adjust the rheostat Rh to pass a small current in the resistance wire AB. Note the voltmeter and ammeter readings.

(3) Go on increasing the current step by step by adjusting the slide contact maker of the rheostat Rh and take about six sets of observation. Note the ammeter and voltmeter readings in each set. Tabulate the observations as detailed below.

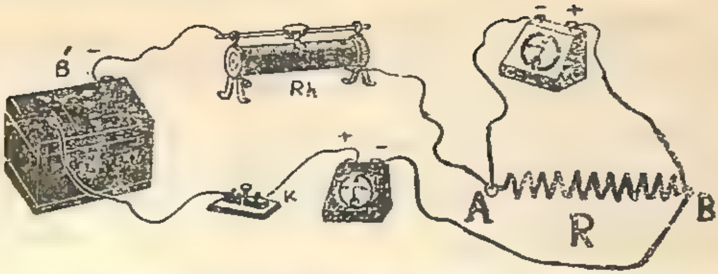


Fig. 12.12. Circuit arrangement for studying the V, I characteristic of a conductor AB.

(4) Take the ratio (V/I) for the voltmeter and the ammeter readings in each case. You will observe that V/I is practically constant.

(5) Draw a graph by plotting the ammeter readings (I) along the X-axis and the corresponding readings of the voltmeter along the Y-axis as shown in Fig. 12.13.

Observations and Calculations

Range of the ammeter =......Amp.
Zero error of the ammeter =..... Amp.
Range of the voltmeter =......Volt.
Zero-error of the voltmeter =......Volt.

Variation of V and I.

Obs. No.	Ammeter readings (I)		Voltmeter readings (V)		$\therefore \frac{V}{I}=R$
	Observed (amp)	Corrected (amp)	Observed (volts)	Corrected (volts)	
1.					
2.					
3.					
4.					
5.					
6.					

Mean $\frac{V}{I}=R=$......ohms.

Conclusion. The potential difference (V) across a conductor is linearly proportional to the current (I) passing through it as indicated by the straight line of Fig. 12.13. The ratio (V/I) is called the resistance R of the conductor.

Graph. The plot of V and I is a straight line passing through the origin. To determine the resistance R from the graph read the current value, say 1.5 amp. corresponding to a given voltmeter reading say 3 volts and take ratio *i.e.* 3 0/1·5=2 ohms. Thus the resistance of the conductor AB is 2 ohms.

$$\frac{V}{I} = \frac{AP}{OP} = \text{Const} = R$$

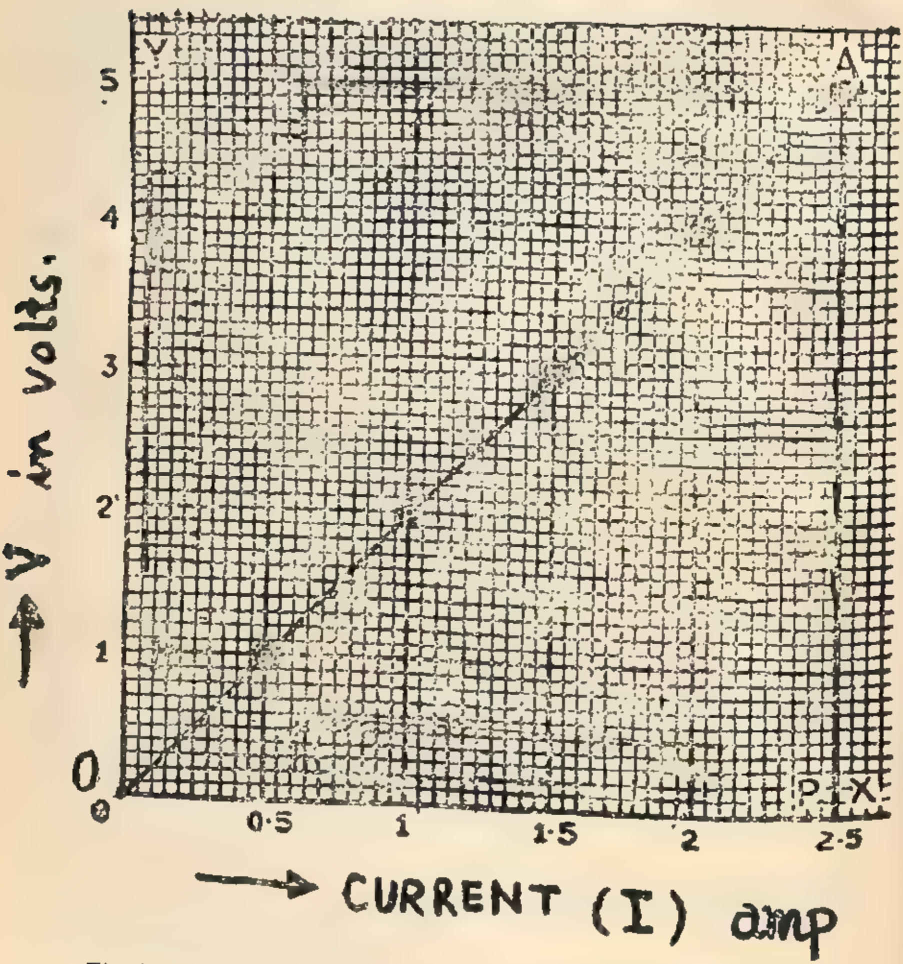


Fig. 12.13. *V, I* characteristic of a conductor (resistor) is a straight line.

Precautions. (1) Draw a neat circuit diagram showing the scheme of connections and get it checked by the teacher.

(2) Clean the ends of the connecting wires by sand paper and then make neat, clean and tight connections.

(3) Get your circuit **connections** checked by the teacher before passing the current.

(4) Close the key only when you are taking readings.

(5) Take care that the battery is not *short circuited* because by doing so, a heavy current is suddenly drawn from the cells due to which the plates of the cells may be destroyed.

(6) Note the zero errors and the ranges of the ammeter and voltmeter.

(7) Positive terminal of ammeter and voltmeter should be connected to the positive pole of the battery and the higher potential terminal B of the wire AB respectively.

(8) A low resistance rheostat should be used in order to change the current smoothly.

(9) The voltmeter must be of high resistance.

(10) Excessive current should not be passed in the wire AB otherwise due to large heating its temperature may increase. Due to increase in temperature the ratio V/I may not remain constant.

§12.0 6. Pupil's Experiment No. 5(*b*).

Aim. To draw the (V-I) characteristics of a vacuum diode valve.

Apparatus. A diode valve preferably with directly heated filament like 5 U 4 or 6×5, the valve holder, filament heater supply ($L.T.$) of about 6 volts and 3 ampere capacity, high tension supply ($H.T.$) to provide positive potential to anode (it may be a dry battery of 45 volts or a suitable power supply), two ammeters of range 100 mA and 2·0 amp., a voltmeter reading upto 100 volts, two rheostat of 10 Ω and 1000 Ω, two plug keys and connecting wires.

Theory. (For the construction of a diode valve read § 13 04).

When the cathode of a diode valve is heated, then electrons are emitted which collect in vicinity of the cathode and form a cluster

called the "space charge". If the anode potential with respect to the cathode is zero or negative, the electrons remain near the surface of the cathode. But when the anode is maintained at a positive potential w.r.t. the cathode, some of the electrons from the "space charge" reach the anode by passing through the vacuum and thus produce "anode current". The anode current increases with the increasing anode potential and finally reaches a constant value. For further increase in the plate potential the anode current does not increase. This constant current is called the "saturation current" and it is larger for the larger filament heating current as shown in Fig. 12.14.

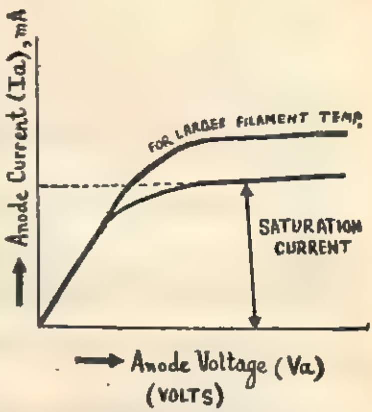


Fig. 12.14. *V*, *I* characteristic of a vacuum diode.

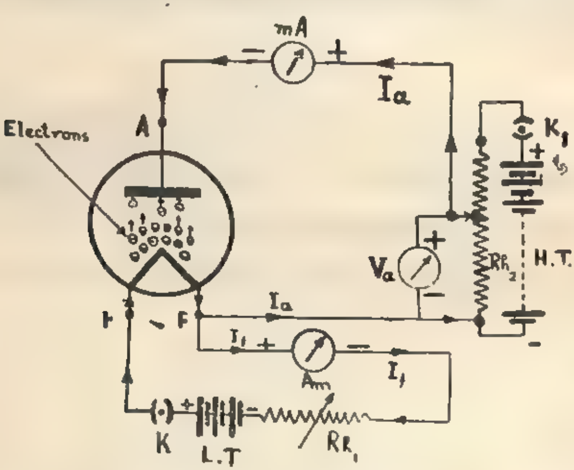


Fig. 12.15. Circuit diagram to determine the VI, characteristic curve of a vacuum diode

Procedure. (1) Draw a circuit diagram as shown in Fig. 12.15 and make circuit connections according to this diagram. Care should be taken to make the connections for H.T. which is a "*potential divider*" with the help of 1000 Ω rheostat (Rh_2) and the battery.

(2) Close the plug key K and adjust the filament current I_f with the help of the rheostat Rh_1 and the ammeter $_mA$, until the filament is red hot. For 5 U 4 or 6×5 diode, it may be about 1 amp.

(3) Apply about 5 volts positive potential to the anode out of the H.T. by closing the key K_1 and note the anode current I_a in the milli-ammeter mA. Note also the voltmeter reading V_a.

(4) Increase V_a in steps of 5 volts or so, and note the corresponding anode current I_a. Care must be taken to keep the filament current constant.

(5) Repeat steps (2), (3) and (4) for two different filament currents.

(6) Tabulate the observations as shown below :

Observations. Table for V_a and I_a.

No. of Obs.	*Filament Current* I_f					
	First Value=...amp.		*Second Value=...amp.*		*Third Value=...amp.*	
	V_a *in volts*	I_a *in mA*	V_a *in volts*	I_a *in mA*	V_a *in volts*	I_a *in mA.*
1.						
2.						
3.						
...						

Graph. Plot a graph between I_a along y-axis and V_a along x-axis for each value of I_f. Plot all the curves on the same graph with the same scale as shown in Fig. 12.14.

Conclusion. The variation of I_a with V_a does not obey **ohm's law,** since the curve is not a straight line.

Precautions. (1) V_a, I_a, and I_f should never exceed the maximum values prescribed for the diode valve.

(2) The negative terminal of the milli-ammeter *mA* should be connected to the anode.

(3) For one set of observations, to get one curve, the value of I_f should be kept constant.

(4) Positive of the H.T. "**potential divider**" should be connected to the anode and the negative to the cathode.

§12.07. Pupil's Experiment No. 5(*c*).

Aim. To draw the ($V-I$) characteristics of a semiconductor at room temperature.

Apparatus. A single crystal of germanium, Ge, having a length of about 2 cm. and an area of cross section of 5 mm. square (the crystal may be either intrinsic or extrinsic *i.e.* p type or n-type) ; a battery of about 6 volts, a rheostat, a milli-ammeter, a voltmeter, zinc sulphate, hydrochloric acid, and soldering arrangements.

Making connections to the crystal. A solution of $ZnCl_2$ is prepared by dissolving $ZnSO_4$ in conc. HCl. This solution is applied

at the end faces by the crystal to clean it. Now soldering material (Zn/Pb) is applied at these faces with the hot soldering* iron. Now copper wires are soldered to the ends of Ge crystal to make connections. Coating soldering material at the ends ensures good electrical contact of the copper with the entire face of the crystal.

Theory. In semiconductors, at room temperature of about 300°K, some charge carriers are present which may conduct electricity. The relation between the current (I) and the applied voltage (V) is linear and it follows ohm's law.

Procedure. (*i*) Arrange the apparatus on the table and make *neat, clean* and *tight* connections as shown in the circuit diagram of Fig. 12.16. Note the zero-error, if any, in the milli-ammeter and the voltmeter.

(*ii*) Insert the plug key K, and adjust the rheostat R to pass a small current through the crystal MN. Note the ammeter and the voltmeter readings.

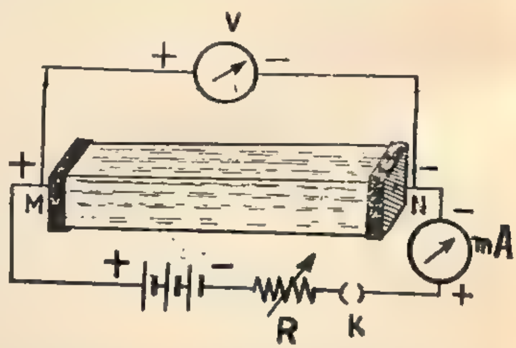


Fig. 12.16. Circuit diagram for the study of V, I characteristic of a semi-conductor.

(*iii*) Now go on increasing the current step by step and record about six observations. Tabulate the observations as in the observation table of the previous expt. No. 5 (*a*).

(*iv*) Calculate the value of (V/I) in each case.

(*v*) Draw a graph by plotting the ammeter readings along X-axis and the corresponding voltmeter reading along the Y-axis. The graph is similar to Fig. 12.13.

Conclusion. As is clear from the graph, V-I characteristic curve of a semi-conductor is a straight line. Thus Ohm's Law is true for a semi-conductor.

Precautions. (*i*) The contacts M and N with the crystal ends must be good.

(*ii*) Usually the current through a semi-conductor is low and hence a milli-ammeter of suitable range should be used.

(*iii*) For other precautions see page 125.

§12.08. Pupil's Experiment No. 7 (*a*).

Aim. To verifiy the laws of resistances in (*i*) series and (*ii*) parallel, by using an ammeter and a voltmeter.

* For soldering read chapter 15.

Apparatus. Two unknown resistances (either two resistance coils or two pieces of resistance wires of different lengths), an ammeter and a voltmeter of suitable ranges, rheostat of about 10 Ω resistance, an accumulator, a plug key, connecting wires of copper and a sand paper.

Theory. Two or more than two resistances, say r_1, r_2, r_3 etc. are said to be connected in **Series** if they are connected end to end as shown in Fig. 12.17 (*a*). The resultant resistance R of the series combination between the ends A and B is given by

$$R = r_1 + r_2 + r_3 \qquad \text{...(i)}$$

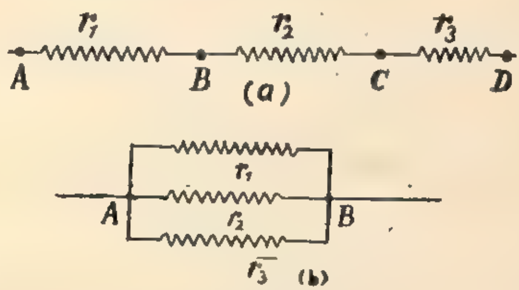


Fig. 12.17.

Thus the resultant resistance R is larger than the individual resistances. Two or more than two resistances, say r_1, r_2, r_3, are said to be connected in **Parallel** when one end of each coil is connected at one point, say A, and their other ends are connected to another common point, say B as shown in Fig. 12.17 (*b*). The resultant resistance R of this parallel combination between ends A and B is given by the equation

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \qquad \text{...(ii)}$$

The resultant resistance R is always smaller than the smallest resistance out of r_1, r_2 and r_3.

Procedure. (1) Determine the individual resistances r_1, r_2, r_3 as explained in § 12.06 by making the circuit connections in accordance with the circuit diagram of Fig. 12.18. The resistance R should

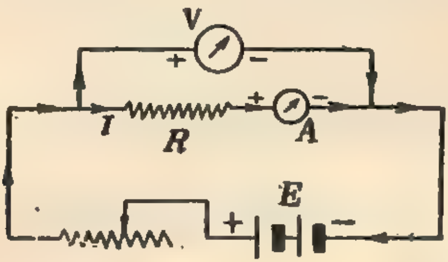


Fig. 12.18. Circuit to determine the resistance R.

be replaced by the individual resistance r_1, r_2 and r_3 in turn. Note the zero errors, if any, of the ammeter and voltmeter pointers.

(2) Connect r_1, r_2 and r_3 in series and complete the circuit connections as shown in Fig. 12.19.

(3) Insert the plug key K and adjust the rheostat for a small current as read in the ammeter Am. Note the ammeter and voltmeter readings.

(4) Increase the current by adjusting the position of slider of the rheostat and record the corresponding readings of ammeter and voltmeter. Thus take four sets of observations and determine the mean value of the resistance of the series combination.

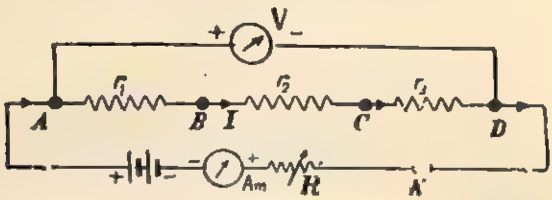


Fig. 12.19. Circuit to determine the resistance of the series combination.

(5) Next connect r_1, r_2 and r_3 in parallel and complete the circuit connections as shown in Fig. 12.20. Repeat steps (3) and (4) and take four sets of observations to get the mean value of the resultant resistance in parallel.

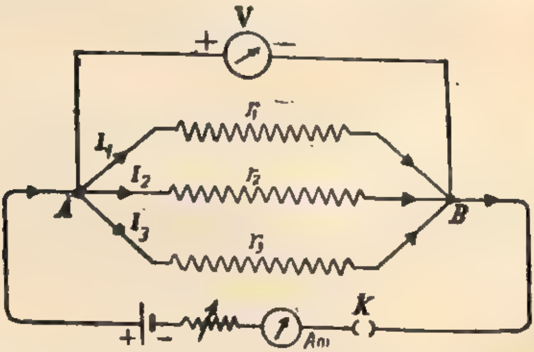


Fig. 12.20. Circuit to determine the resistance of parallel combination.

(6) Record the observations as detailed below :

[**Observations :**

Zero reading of voltmeter =...volt.
Zero reading of ammeter =...amp.
Least count of the voltmeter =...volt.
Least count of the ammeter =...amp.

Resistance (ohm)	Obs. No.	Voltmeter Reading (V)		Ammeter Reading (I)		Resistance $=V/I$ ohm.	Mean resistance (ohm.)
		Observed (volt)	Corrected (volt)	Observed (Amp.)	Corrected (Amp.)		
r_1	1.						
	2.						
	3.						
	4.						
r_2	1.						
	2.						
	3.						
	4.						
X_1 (r_1 and r_2 in series)	1.						
	2.						
	3.						
	4.						
X_2 (r_1 and r_2 in parallel)	1.						
	2.						
	3.						
	4.						

Calculations and Verification

(*a*) Equivalent resistance of the resistors in **Series**

(*i*) by experiment $X_1=$......ohm.

(*ii*) by calculation $R_1=r_1+r_2$
$=$......ohm.

(*b*) Equivalent resistance of the resistors in **Parallel**

(*i*) by experiment $X_2=$......ohm.

(*ii*) by calculation $1/R_2=1/r_1+1/r_2$
$=$......

$\therefore$ $R_2=$......ohm.

Result. Within the limits of experimental error, the experimental values (X) are equal to the calculated values (R) of the resistance combinations, hence the *laws of resistances in series and parallel are verified*.

Precautions. (*i*) The lengths of the end portions of the resistors used for the terminal connections should be same in all the cases and hence suitable marks should be made with ink etc.

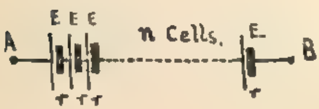
(*ii*) Rest of the precautions are the same as on page 125.

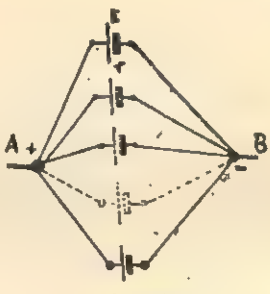
§12.09. Pupil's Experiment No. 7 (*b*).

Aim. To study the grouping of cells in series and parallel in order to have the maximum current.

Apparatus. Three cells of the same kind, (say lead accumulators or Leclanche cells or dry cells) a rheostat (say 20 ohms), one voltmeter and one ammeter of suitable ranges and connecting wires.

Theory. The e.m.f. or current supplied by a cell may be insufficient for many purposes. The required e.m.f. and the current may be achieved by combining many cells. The two usual type of combinations are as under.

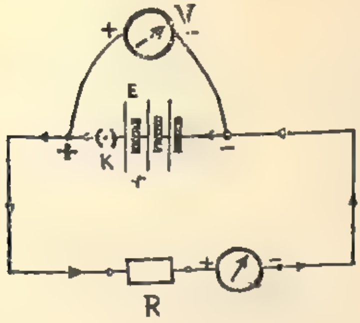




(*a*) Combination of cells in series. (*b*) Combination of cells in parallel.

Fig. 12.21.

(I) Series Combination of Cells. Two or more cells are said to be connected in series when the positive terminal of one cell is connected to the negative terminal of the next and so on as shown in Fig. 12.21 (*a*). Let there be n identical cells each of e.m.f. E and internal resistance r, all connected in series to supply current in a resistance R as shown in Fig. 12.22 (*a*). The total e.m.f. of the series combination is nE and the total internal resistance of all the cells is nr. This resistance nr acts in the circuit in series with the external resistance R as shown in Fig. 12.22 (*b*). Thus the total resistance of the circuit is $(nr+R)$. The current I in the circuit is given by Ohm's Law as—



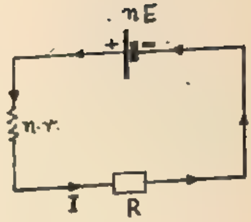


Fig. 12.22.

$$I=\frac{nE}{nr+R} \qquad \ldots(1)$$

If the internal resistance nr is negligible $(nr \ll R)$ in comparison to the external resistance R, then

$$I=n\cdot\frac{E}{R} \qquad \ldots(2)$$

Thus the current I due to the series combination is n times the current due to a single cell (since current due to a single cells is E/R).

However, if the internal resistance is large in comparison to the external resistance R, there may be gain in the e.m.f. (*i.e.* nE) but the current sent through R may not increase. Thus such a series combination may not be helpful.

II. Parallel Combination of Cells. In this type of grouping of cells the positive terminals of all the cells are connected at one point (say A) and their negative terminals are connected at another common point (say B) as shown in Fig. 12.21 (b). Let there be n identical cells, each of e.m.f. E and internal resistance r. Let these cells be connected in parallel to supply current in an external resistance R as shown in Fig. 12.23 (a). The resultant e.m.f. across the points A, B is E (*i.e.* equal to e.m.f. of the individual cell). The parallel combination of the internal resistances acts in series with R. The equivalent resistance of the parallel combination is obtained as below.

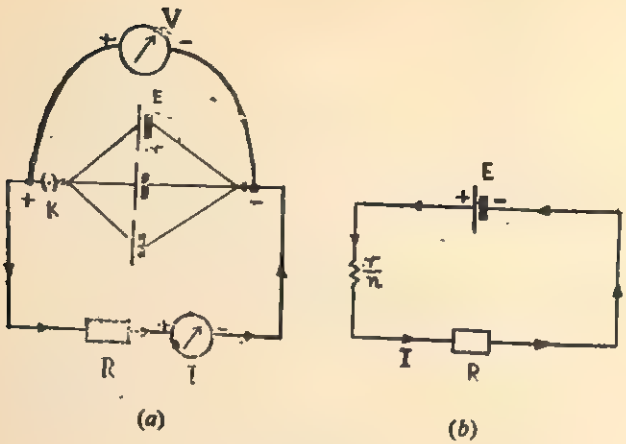


Fig. 12.23

$$\frac{1}{r_{equ}}=\frac{1}{r}+\frac{1}{r}+\ldots+\frac{1}{r}$$

$$=\frac{n}{r}$$

$\therefore$
$$r_{equ}=\frac{r}{n} \qquad \ldots(1)$$

The current I through the resistance R is given by Ohm's Law [See Fig. 12.23 (*b*)] as below :—

$$I=\frac{E}{r/n+R} \qquad \ldots(2)$$

Let us discuss equation (2) under two special conditions. (*i*) When r/n is much smaller than R *i.e.* $r/n \ll R$, we get from equation (2)

$$I=\frac{E}{R}$$

i.e. the current I is equal to the current due to a single cell. Thus there is no use of the parallel combination if $r \ll R$.

(*ii*) When $r/n \gg R$, we get from equation (2),

$$I=\frac{E}{r/n}=n.\frac{E}{r}$$

i.e. the resultant current I is n times the current due to a single cell.

Conclusion. From these two kinds of the grouping of cells we come to the conclusion as under.

(*a*) When the internal resistance of cells is negligible in comparison to the external resistance of a circuit, then maximum current in the circuit is obtained by connecting the cells in **Series.**

(*b*) When the internal resistance of the cells is large in comparison to the external resistance, then maximum current through the external resistance is obtained by connecting the cells in **Parallel.**

Procedure. (*i*) Measure the e.m.f. of the individual cells, with a voltmeter, which are in good working condition. Select the cells of same type and of equal e.m.f.

(*ii*) Make the circuit connections as shown in Fig. 12 2'.

(*iii*) Close the key *K* and with the help of the Resistance box introduce the resistance *R* to get a current of about 0 2 amp. or less. Note this current I_1 and voltage V_1 from a single cell. Repeat the above experiment for three more values of *R*.

(*iv*) Connect all the three cells in series as shown in Fig. 12.22 (*a*).

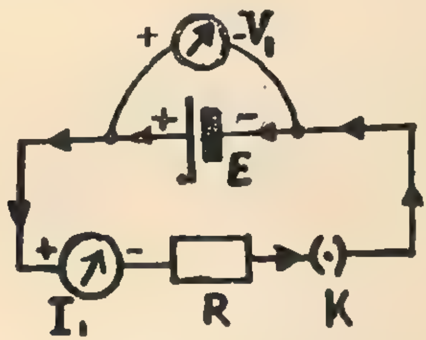


Fig. 12.24.

(*v*) Note the voltage *V* and the current *I* for the same four values of *R* as taken in step (*iii*).

(*vi*) Now connect all the cells in parallel as shown in Fig. 12.23 (*a*). Note the readings of voltmeter and ammeter for the same four values of *R* as taken earlier.

(*vii*) Record the observations as below.

Observations

Zero error in the voltmeter	=	...volt.
Zero error in the ammeter	=	...amp.
Least count of the voltmeter	=	...volt.
Least count of the ammeter	=	...Amp.
E.M.F. of each cell as measured by the voltmeter		...volts.

Observation No.	Resistance R (in Ω).	Potential difference and current due to a single cell		Potential difference and current due the grouping of cells in			
				SERIES		PARALLEL	
		P. Diff. (V_1) (in volt)	Current (I_1) (in amp.)	P. Diff. V (in volt)	Current I (in amp.)	P. Diff. V (in volt)	Current I (in amp.)
1.							
2.							
3.							
4.							

Result. It is clear from each observation that for the

(*a*) Series combination $I \simeq 3I_1$ and $V \simeq 3V_1$.

(*b*) Parallel combination $I \simeq I_1$ and $V \simeq V_1$.

Conclusion. In order to get the maximum E.M.F. and the maximum current by the combination of many cells, they must be connected in **Series** when the internal resistance of the cell is negligibly small as compared to the external resistance of the circuit.

Precautions. (1) The cells chosen should be in good working condition *i.e.* their internal resistance must be small. The e.m.f. of each cell should be the same.

(2) Short circuiting of the cells must be avoided.

(3) The resistance R should be large in comparison to the internal resistance of the cells. For a lead accumulator or a leclanche cell, R should not be less than 8 or 10 ohms.

4. ELECTROLYSIS

§12.10. Points to Remember

(1) **Electrolysis.** Some liquids like salt solutions, are capable of carrying electrical current. These solutions which can carry current are called *electrolytes* and the plates or rods where the current enters or leaves the electrolyte are called *electrodes*. The vessel containing the *electrolyte* and the *electrodes* is called *Voltameter.*

The process of decomposition of salt solutions by passage of electric current through them is called *Electrolysis*. The products of the decomposition are called *ions.*

(2) The mass of ions liberated at either electrode is directly proportional to the current 'i' and the time 't' for which the current is passed.

Thus $\quad m \propto it$

or $\quad m = Z\, it$

where Z is a constant, called electro-chemical equivalent (E.C.E.) of electrolyte and depends upon its nature.

(3) The mass of an ion liberated by a given quantity of electricity ($i.t.$) is directly proportional to the chemical equivalent of the ion.

§12.11. Demonstration Expt. No. 4.

Aim. To demonstrate the "electrolysis effect" with the help of "Copper Sulphate Solution".

Apparatus. A glass vessel, a copper plate, a brass plate (each with one small hole), copper sulphate crystals, a battery of about 4 volts, another glass vessel to prepare solution, connecting wire and a rheostat.

Procedure. (i) Assemble the apparatus on the table. Clean the brass and the copper plates with fine emery or sand paper. Wash the plates after rubbing and finally dry them. Weigh the cleaned and dried plates with the help of a physical balance.

(ii) Prepare a saturated solution of copper sulphate crystals in water to which few drops of sulphuric acid is added. Take this solution in a glass container.

(iii) Now dip the two plates in the solution and complete the circuit connection as shown in Fig. 12.25. A battery is connected to complete the circuit in such a way that its negative terminal is connected to the brass plate.

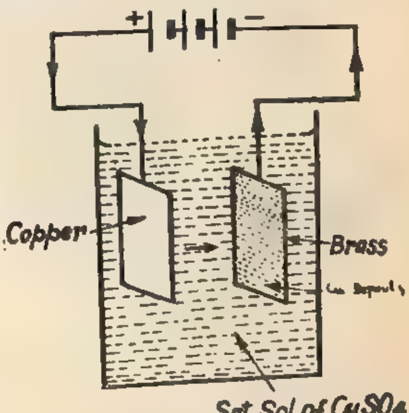


Fig. 12.21. Deposition of copper on brass plate.

(iv) Let the current pass for about 10 minutes.

(v) Now break the battery connections and take out the plates and wash them gently in running water. Dry them with filter paper and weigh them accurately again.

Observations :

Mass of the brass plate in the beginning $= m_1 = \ldots$ gm.

Mass of the copper plate in the beginning $= m_2 = \ldots$gm.

Mass of the brass plate after deposition $=m_1'=$...gm.

Mass of the copper plate after electrolysis $=m_2'=$...gm.

∴ Increase in the mass of the brass plate $=m_1'-m_1=$...gm.

and Decrease in the mass of the copper plate$=m_2-m_2'=$...gm.

Thus $(m_1'-m)=(m_2-m_2')$.

Conclusion. Copper is deposited on the cathode plate in the process of electrolysis and there is a corresponding dissolution of copper from the anode in the electrolyte.

5. MICROPHONE AND HEADPHONE

§ 12.12. Points to Remember

(1) The electrical resistance of a lump of carbon granules decreases with increasing pressure on them.

(2) **Microphone.** *It is a device to convert sound energy into electrical energy.* Microphone is also called mouth piece or transmitter when used in a telephone circuit. The popular type of modern microphone is a *carbon granule microphone.* This microphone consists of a large number of carbon granules (C) packed between carbon plates (M) as shown in Fig. 12.26. A thin and light metal diaphragm D is clamped to the plate (M). Two metal terminals (L) are attached to the two plates (M) for outer connections.

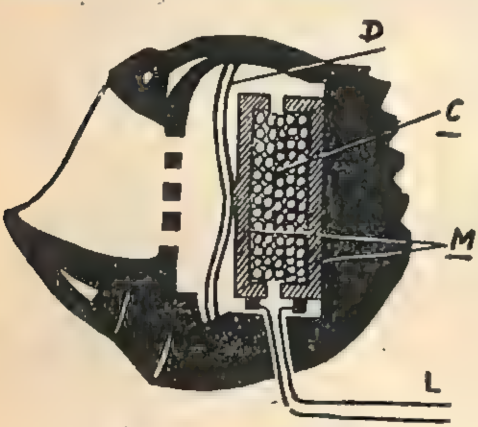


Fig. 12.26. Microphone.

When a battery is connected across the terminals (L), a current flows in the closed circuit consisting of the battery and the carbon granules. When somebody speaks near the microphone, sound waves strike the diaphragm D. The *pressure* on the diaphragm varies according to the variations in the sound intensity. As a consequence the carbon granules undergo corresponding variation of pressure on them. When the granules are compressed the resistance of the granules decreases. But when they become loose due to decrease in pressure, the poor contact between them increases the resistance. Thus due to variations in the resistance of the carbon granules, there is a *fluctuating* current in the circuit. The *fluctuations* in the current are at the frequency of the sound waves.

(3) A magnetic thin disc kept near an electromagnet vibrates according to the variations or fluctuations of current in the electromagnet.

(4) **Headphone.** This instrument is also called an *ear piece* or a *receiver*. *The function of a headphone is to convert electric energy into sound energy*. Thus the function of a headphone is reverse to that of a microphone. A modern type of headphone is shown in Fig. 12.27.

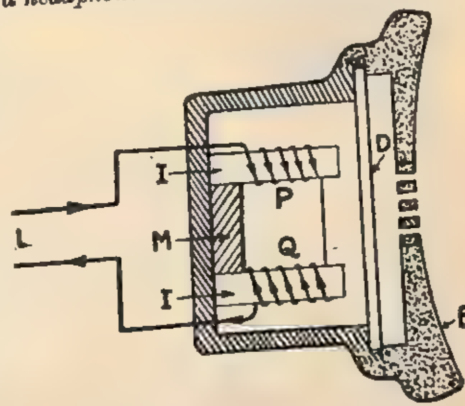


Fig. 12.27. Headphone.

A headphone or an earpiece of a telephone consists of a permanent magnet M. Two coils P and Q are wound over round soft iron pieces (I) as shown in Fig. 12.27. The soft iron pieces are fixed at the opposite ends of the magnet M. The two coils P and Q are connected in series so as to have currents in opposite directions. The two ends of the coil combination is connected to leads (L) for outer connections. There is a thin magnetic disc D, called the diaphragm, near the free faces of (I). When a person talks into a microphone at the other end of the telephone line, a fluctuating current flows in the coils P and Q of the *ear piece*, which results into the variation of the strength of magnetic field. This causes the electromagnet (I) to exert varying pull on the diaphragm D. The diaphragm D thus vibrates and reproduces a copy of the original sound waves which entered the microphone at the other end.

§12.13. Demonstration Experiment No. 7.

Aim. To prepare a model of a "*microphone*" and a "headphone" and demonstrate them to the class.

Apparatus. (*a*) *For microphone.* A thin metal (aluminium) plate, a metal dish, carbon electrodes of waste dry cells or carbon block, connecting wire, a sensitive galvanometer and a battery.

(*b*) *For Headphone.* A U-shaped permanent magnet, enamelled thin copper wire, a diaphragm disc from some old headphone or from the junk, connecting wire and a small wooden box.

Procedure. *Model making of microphone* :

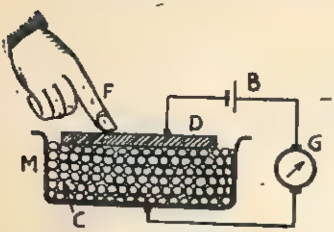


Fig. 12 28. Model of a headphone.

(1) Prepare carbon granules (C) by hammering the carbon rods of waste dry cells and place it in the aluminium dish (M) as shown in Fig. 12.28.

(2) Make connections as shown.

(3) The small current in the circuit as shown by the galvanometer G is increased by pressing the disc D.

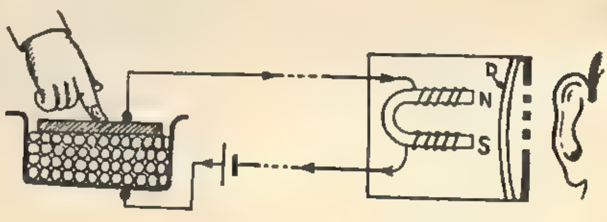
(4) Now if you blow air with mouth on the disc D, again there is an increase in the current as indicated by the galvanometer.

Conclusion. The fluctuating pressure due to sound waves or some other source, produces a fluctuating current in the circuit. This essentially, is the principle of a "*microphone*".

Model Making of a Headphone

(*i*) Wind a large number of turns of the enamelled copper wire on the horse-shoe magnet NS as shown in Fig. 12.29 (b). Arrange the coiled magnet and the diaphragm D as shown in the Fig. 12.29 (b) in a suitable wooden box having a few holes in one of its faces near D as shown.

(*ii*) Connect the microphone [Fig. 12.29 (a)] to this headphone [Fig. 17.29 (b)] as shown in the diagram. In actual demonstration, the microphone set and the headphone set should be kept at a large distance.



(a) (b) Head Phone.

Fig. 12.29. Model of a headphone.

(*iii*) If you press intermittently and frequently the disc D of the microphone with a finger or blow air on it with mouth, you will listen a sound due to vibrations of the diaphragm D of the headphone. This illustrates the principle of a headphone along with a microphone.

QUESTIONS

1. Complete the following statements by selecting one alternative from those given within brackets :

(a) A Leclanche cell gives a.........current. (constant, intermittent)

(b) A Daniel cell gives a......... current. (constant, intermittent)

(c) A storage cell stores.........energy. (electric, chemical)

(d) ....cell is used for electric bells. (Daniel, Leclanche)

(e) The current used for electrolysis is......... (A.C., D.C.)

(f) Dry cell is a modified form of.........cell. (Daniel, Leclanche)

2. Answer the following questions :

(a) When do we connect cells in parallel and when do we connect them in series ?

(b) During electrolysis, to which electrode do the metals go ?

3. Complete the following statements by selecting correct alternative from those given in brackets :

(a) An ammeter is connected in......with the rest of the circuit. (parallel, series)

(b) A voltmeter is connected in......with the rest of the circuit. (parallel, series)

(c) An ammeter has......resistance. (high, low)

(d) A voltmeter has......resistance. (high, low)

(e) When the temperature of a conductor increases, its resistance...... (decreases, increases)

(f) The resistance of a perfect insulater is...... (zero, infinite)

(g) The resistance of a perfect conductor is...... (zero, infinite)

(h) A thin wire will introduce a .....resistance than a thick wire of the same length and same material. (smaller, larger)

(i) If you want to decrease the resistance then you will connect the wires in...... (series, parallel)

(j) Lamps used for street lighting are connected in...... (series, parallel)

(k) Lamps used for household lighting are connected in...... (series, parallel)

MAGNETISM

§ 12.14. Points to Remember

For the definition of North and South Poles, magnetic axis, magnetic meridian, pole strength magnetic moment etc. read articles 16.8, 9, 10, of the reference given in the footnote. Also read article 16.11 of the same reference, regarding the mapping of the magnetic lines of force.

§ 12.15. Locating the Poles and Magnetic Length

Take a bar magnet and place it on a paper fixed on a drawing board such that its axis is along the magnetic meridian as shown in Fig. 12.30 (*b*). Make the boundary of the magnet on the paper with a sharp pencil. Choose a point A near the corner of north pole of the magnet and place a compass needle with its one end coinciding with A and mark the point B corresponding to its other end. To mark the point B accurately, the help of a thread stretched between two pins may be taken as shown in Fig. 12.30 (*a*). Move the compass needle to the position 2 and bring its first end towards B and then mark the position C of its other end. Similarly make the point D and finally join *ABCD* to make a straight line. In the same manner mark the other two lines *A'B'C'D'* and *A''B''C''D''* also. These lines meet at the point *N*. This point *N* is the position of **North Pole** of the magnet.

Similarly locate the position of the **South Pole** *S*. The distance between *N* and *S* is called the magnetic length. The magnetic length of a bar magnet is nearby 7/8th of its **Geometrical Length**.

§ 12.16. Pupil's Experiment No. 6 (*a*).

Aim. (*i*) To map the magnetic lines of force due to a bar magnet with its north pole pointing towards the magnetic north and to locate the positions of the neutral points.

(*ii*) To calculate the magnetic moment and the pole-strength of a magnet (H=0·32. oersted at Delhi is given).

Apparatus. Drawing board, a plane sheet of paper, a compass needle, a bar magnet, drawing board pins, a half metre scale, a piece of chalk and a sharp pencil.

Theory. The intensity of the field at any point in the field of a bar magnet is due to the combined effect of the *magnet* and the *earth's magnetic* field. When the north pole of a bar magnet points

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Note. Physics (Class IX-X) NCERT, 1975, pp. 120-22.

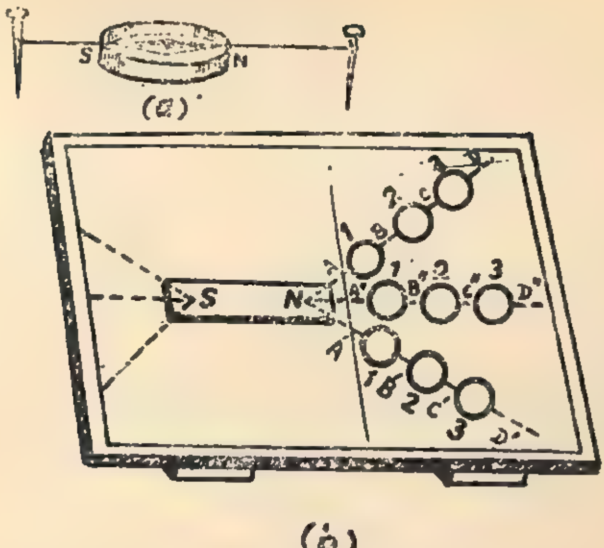


Fig. 12.30. Locating the poles of a magnet.

towards the geographical north then at the points N_1 and N_2 (which are on the broad side on position), the intensities of the magnetic fields F and H are equal and opposite, F and H being the intensities of the magnetic fields due to the magnet and the earth respectively. But, with reference to Fig. 12.31, F is given by the following equation :

$$F=\frac{M}{(d^2+l^2)^{3/2}} \qquad ...(1)$$

where M is the magnetic moment of the magnet. Also, for the points N_1 and N_2

$$F=H \qquad ...(2)$$

Thus from equations (1) and (2), we get

$$M=H\,(d^2+l^2)^{3/2} \qquad ...(3)$$

Also

$$M=2ml \qquad ...(4)$$

where m is the pole-strength of the magnet.

From equations (3) and (4), we get

$$m=\frac{H(d^2+l^2)^{3/2}}{2l} \qquad ...(5)$$

Thus by measuring d and l, we can calculate M and m from equations (3) and (5) respectively. The value of H depends upon the place and it may be taken as 0.31 oersted for Delhi.

These points N_1 and N_2 where the earth's magnetic field is neutralized by the magnets are called **Null Points** or **Neutral Points.**

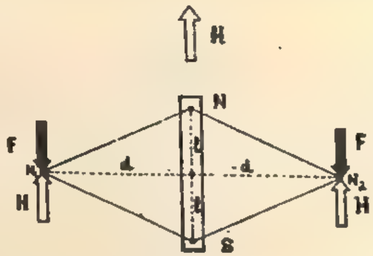


Fig. 12.31.

Procedure. (*i*) Fix a sheet of plane or drawing paper on a drawing board with brass pins or quickfix. Place a compass needle

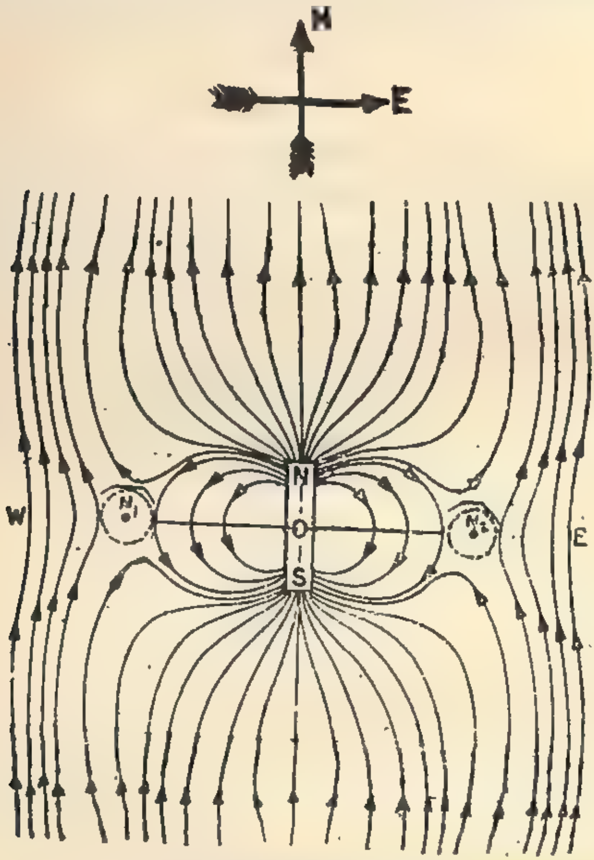


Fig. 12.32. Magnetic lines of force with *N*-pole pointing towards the north.

in the centre of the paper sheet and rotate the board till the length of the needle is parallel to the edge of the paper. Tap the paper gently and then mark points against the ends of the needle. The line *NS* joining these points will be along the magnetic meridian. Mark this position of the board by drawing its boundary with a piece of chalk.

Place the magnet on the line *NS* symmetrically in such a way that its north pole points towards the geographical north and draw the boundary of the magnet with a sharp pencil.

(3) Place a compass needle near the north pole of the magnet and tap it gently. Make the points on the paper against the ends of the needle. Move the needle forward till its south pole coincides with the second point marked earlier and mark the third point against its north pole and so on. In this way mark positions of the north pole of the compass needle step by step till the south pole of the magnet is reached. Join all the points marked by a free hand drawing and thus a magnetic line of force is mapped.

Fig. 12.33.

(4) Plot the lines of force on both the sides of the magnet, indicating the direction by arrow-heads pointing from north pole towards the south pole. More lines should be drawn near the **Neutral Point** region. Around the neutral point region, the lines of force should form a curvilinear quadrilateral as shown in Fig. 12.33. Mark the boundary of the compass needle within this region. The **Centre** of the circular boundary gives the **Neutral** or **Null Point.**

To locate neutral points accurately. Since the resultant magnetic field at the neutral point is zero, the needle may point in any direction. To test whether the needle is in this position or not, an iron nail or pin is brought near the compass needle which will be attracted by it. Now remove the nail or the pin away slowly from the needle without disturbing it. There should be no change in the direction of the needle.

(5) Determine the position of the poles as discussed in § 12.15 and determine the magnetic length $2l$.

(6) To determine, M and m, determine also the perpendicular distance 'd' from the neutral points N_1 and N_2 to the magnetic axis as shown in Fig. 12.31.

Observations

Magnetic length of the magnet $2l=$......cm.

$d_1=$......cm.

$d_2=$......cm.

$$\therefore\ d=\frac{d_1+d_2}{2}=\text{......cm.}$$

$H=0{\cdot}31$ oersted.

Calculations and Result

(*i*) Magnetic Moment $M = H\ (d^2+l^2)^{3/2}$

$=\ldots\ldots$ C.G.S. Units.

(*ii*) Pole strength $m = \frac{H}{2l}\ (d^2+l^2)^{3/2}$

$=\ldots\ldots$ C.G.S. Units.

Precautions

(1) The boundaries of the drawing board and the magnet should be drawn with a piece of chalk and a sharp pencil respectively.

(2) From the beginning of the experiment till the end, there should be no magnetic material in the vicinity of the magnet. The drawing pins, for this reason, should be of brass.

(3) Many lines should be drawn near the **Neutral Point.**

(4) Position of the neutral point should be traced with the help of a iron nail accurately.

(5) The position of the drawing board and the magnet should not be disturbed during the course of the experiment.

(6) The direction of the lines of force should be indicated by arrow heads.

§12.17. Pupil's Experiment No. 6 (*b*).

Aim. (*i*) To map the magnetic lines of force due to a bar magnet with its north pole pointing towards the magnetic south and to locate the positions of the neutral points.

(*ii*) To calculate the magnetic moment and the pole-strength of the magnet.

Apparatus. Same as in the previous experiment No. 6 (*a*).

Theory. When a bar magnet is placed with its axis along the north south direction such that its north-pole faces the south, then the Neutral Points N_1 and N_2 lie on the axis of the magnet on its either side as shown in Fig. 12.34. The position of these points N_1 and N_2 are in the **End on Position** with respect to the magnet and hence the intensity of the magnetic field F due to the magnet at these points is given by the equation -

$$F=\frac{2Md}{(d^2-l^2)^2} \qquad \ldots (1)$$

in which M and l are the magnetic moment and half the magnetic length of the magnet respectively, d is the distance of either point N_1 and N_2 from the centre O of the magnet.

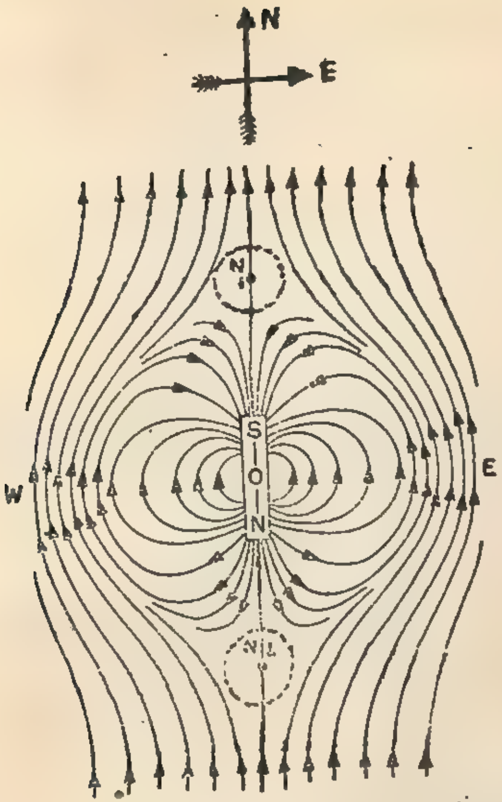


Fig. 12.34. Locating the lines of force when the North-pole points toward the south.

At the neutral points $F=H$ where H is the horizontal component of earth's magnetic field. Thus from equation (1) we get

$$H=\frac{2Md}{(d^2-l^2)^2}$$

or

$$M=\frac{H\,(d^2-l^2)^2}{2d} \qquad ...(2)$$

Since $M=2ml$ where m is the pole-strength of the magnet, we get from equation (2),

$$m=\frac{M}{2l}=\frac{H\,(d^2-l^2)^2}{4ld} \qquad ...(3)$$

By measuring d and l, the magnetic moment M and the pole-strength m of the magnet can be calculated with the help of equations (2) and (3) respectively.

Procedure. (*i*) The magnet should be placed on a drawing board as explained in the procedure of the expriment No. 6 (*a*). However, in this case the north pole N of the magnet should face the geographical south pole.

(*ii*) The magnetic line of force should be mapped as in the experiment No. 6 (*a*).

(*iii*) The location of the neutral points should be judged accurately as explained in the experiment 6 (*a*).

(*iv*) Measure the quantities d and l.

Observations :—

Magnetic length of the magnet $2l=$......cm.

(at Delhi) $H=0{\cdot}32$ oersted.

Distance of the point N_1 from the mid-point O of the magnet, $d_1=$......cm.

Distance of the point N_2 from the mid-point O of the magnet, $d_2=$......cm.

$\therefore$ The mean distance $d=\dfrac{d_1+d_2}{2}=$......cm.

Calculations and Result

(*i*) Magnetic moment of the magnet $M=\dfrac{H\,(d^2-l^2)^2}{2d}$

$=$......C.G.S. units.

(*ii*) Pole-strength of the magnet $m=\dfrac{H\,(d^2-l^2)^2}{4ld}$

$=$......C.G.S. units.

Precautions. Same as in experiment No. 6 (*a*).

MAGNETIC EFFECTS OF CURRENT

§12.18. Points to Remember.

(*i*) An electric current is always accompanied by a magnetic field.

(*ii*) The magnetic lines of force due to a current passing through a straight conductor are circular around the conductor.

(*iii*) The magnetic lines of force due to a current passing through a coil are perpendicular to the plane of coil at the centre.

(*iv*) The direction of the magnetic field produced by the current is given by the rules discussed in §12.02.

(*v*) The magnitude of the magnetic field depends upon (*a*) the strength of the current, (*b*) the number of turns of the wire, (*c*) the distance of the point from the wire and (*d*) the medium between the point and the wire.

(*vi*) **Electromagnet.** When a coil, wound over a soft iron core with the help of insulated copper wire, contains a current then

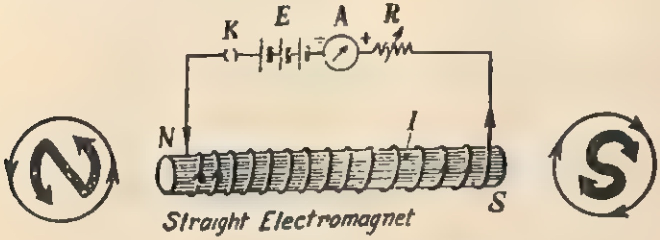


Fig. 12.35.

it behaves like a magnet. Such an arrangement is called an *Electromagnet.* Such an arrangement is shown in Fig. 12.35.

§12.19. Suggested Pupil's Activity No. 2.

Aim. To design and study an electromagnet.

Apparatus. Nearly 2 metres of insulated copper wire of about 24 S.W.G.,* small nails, two or three cells, a key, connecting wire, a compass needle and an iron bolt about 5 cm. long with a nut and two washers.

Procedure. (*i*) Place a washer at each end and screw the nut so that it is away from the screw-head.

(*ii*) Wind layers of insulated copper wire on the bolt between the two washers as shown in Fig. 12.36.

(*iii*) Apply adhesive tape on the windings near the two washers to avoid unwinding.

(*iv*) Connect two cells in series and join the electromagnet as shown in Fig. 12.37.

(*v*) Plug in the key to energise the electromagnet and bring its one end near a tray of nails. Some nails are attracted by the the magnet. Count the number of the nails attracted.

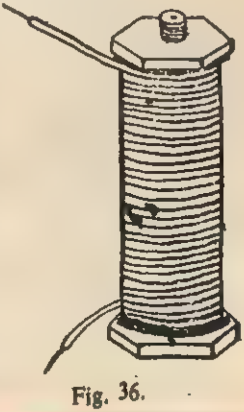


Fig. 36.

* Standard Wire Gauge.

(*vi*) Now disconnect the circuit and you will observe that the nails are dropped in the tray. What happened to the magnetic property of the coil ?

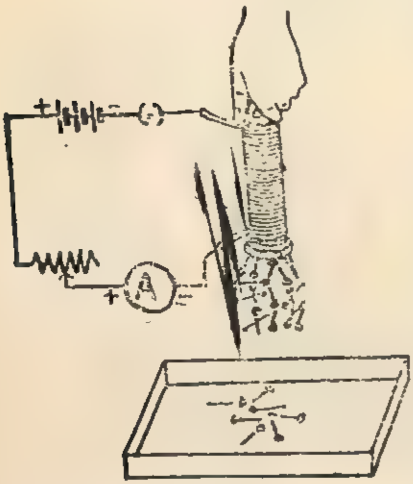


Fig. 12.37

(*vii*) Increase the current and repeat step (*v*). You will observe that the number of the nails attracted is increased.

(*viii*) Reduce the number of turns of the electromagnet winding and then repeat step (*v*). You will observe that the magnetic effect is reduced.

(*ix*) Repeat all the above steps by taking a nut and bolt of *brass*. You will observe that the magnetic strength of the electromagnet is considerably reduced.

Observations :

S. N.	No. of turns of Electromagnet winding	Number of nails picked up for the current of			
		I_1=...amp.		I_2=...amp.	
		Iron Bolt	Brass Bolt	Iron Bolt	Brass Bolt
1.	20 turns				
2.	40 turns				

Conclusions. (*i*) The magnetic property exists so long as the current is there in the coil.

(*ii*) Intensity of the magnetic field is increased by increasing the current.

(*iii*) Intensity of the magnetic field is increased by increasing the number of turns of the electromagnet coil.

(*iv*) Intensity of the magnetic field is increased by inserting the iron block in the electromagnet coil.

Precautions. (*i*) Copper wire used for the winding should be insulated.

(*ii*) Iron nails used should be small in size and large in number.

(*iii*) A plug key should be used to complete the circuit for a time not more than the time genuinely required.

§12.20. Suggested Pupil's Activity No. 3 (*a*).

Aim. To study the magnetic field due to a straight conductor carrying current.

Apparatus. Insulated copper of (24 or 28 SWG) about 20 metres in length, a cardboard, white paper, iron filings, a compass needle, a rheostat, an ammeter, and three cells.

Procedure. (*i*) Fix a white paper sheet on a cardboard and then make a hole of suitable size in the centre of the board.

(*ii*) Make a coil of long insulated copper wire such that its one side passes vertically through the hole in the cardboard which is held horizontally.

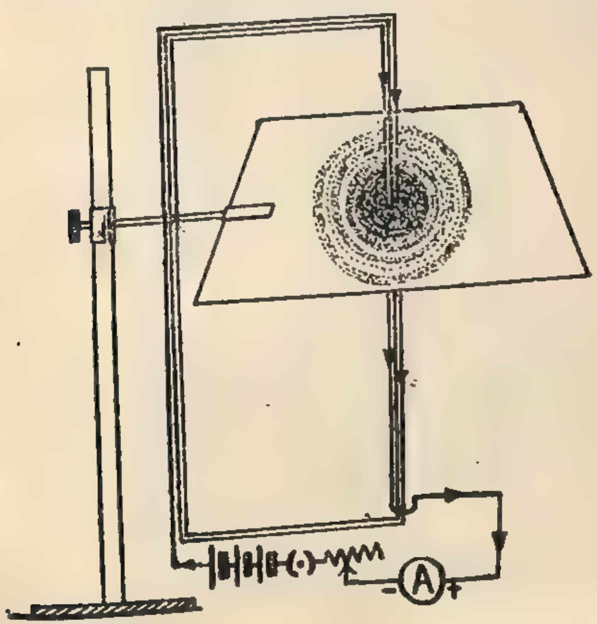


Fig. 12.38.

(*iii*) Arrange the circuit connections by connecting three cells in series with a plug key, a rheostat and an ammeter across the two ends of the coil as shown in Fig. 12.38.

(*iv*) Sprinkle a thin and uniform layer of iron filings on the cardboard and then switch on the current by closing the plug key. Adjust the current to about 3 amps. Now tap the cardboard gently. You will observe that the filings are set in a series of concentric circles about the wire as centre as shown in Fig. 12.38.

(*v*) Now blow off the iron filings. Plot the circular magnetic lines of force with the help of a compass needle as shown in Fig. 12.39. The north pole *n* of the plotting compass point in the direction of the magnetic field.

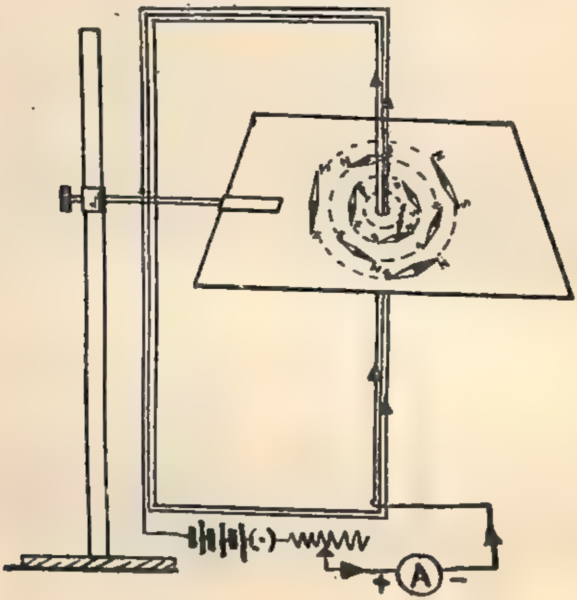


Fig. 12.39. Plotting the magnetic lines due to a straight current.

(*vi*) Now reverse the direction of the current in the coil and again plot the magnetic lines of force. You will observe that by reversing the direction of current the direction of the magnetic lines of force is also reversed. Also analyse that the direction of the magnetic field is in accordance with the right hand thumb rule as discussed in §10·02.

§12.21. Suggested Pupil's Activity No. 3 (*b*).

Aim. To study the magnetic field due to a circular coil carrying current.

Apparatus. A circular coil containing about 20 turns of insulated copper wire fitted on a wooden frame, iron filings, three cells, a rheostat, an ammeter, a plug key and a white paper.

Procedure. (*i*) Fix a white paper sheet on the wooden board kept horizontally on which the coil is fixed such that its plane is

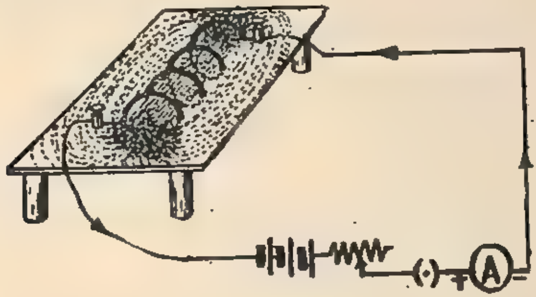


Fig. 12.40.

vertical as shown in Fig. 12.40.

(*ii*) Connect three cells, a rheostat, an ammeter, a plug key and the coil, all in series as shown in Fig. 12.40.

(*iii*) Sprinkle a thin and uniform layer of iron filings on the cardboard and then pass the current in the coil by closing the plug key. Adjust the current to about 3 amps. Tap the cardboard gently. Observe the pattern into which the iron filings are arranged.

(*iv*) Now blow off the iron filings and trace the path of magnetic lines of force with a plotting compass.

(*v*) Reverse the direction of the current in the coil and again trace the lines of force. You will find that the direction of the magnetic field produced is now reversed.

QUESTIONS

1. Select the proper alternative from those given within brackets and complete the following statements :
   (*a*) Permanent magnets are made of......(soft iron, steel).
   (*b*) Electro-magnets are made of......(soft iron, steel).
   (*c*) Like poles...while unlike poles.. each other. (attract, repel)
   (*d*) ...is the sure test of magnetism. (attraction, repulsion)
   (*e*) Iron filings stick more at the...of a bar magnet. (centre, ends)
   (*f*) Lines of force.. longitudinally and...laterally. (expand, contract)
   (*g*) Electromagnet is...magnet. (permanent, temporary)
   (*h*) In induction.. pole is induced on the nearest end. (like, opposite)

2. Complete the following statements :
   (*a*) Magnetic intensity at a point is the force experienced by...

(*b*) A magnetic pole has a unit strength which when placed in.. at a distance of...from...pole repels it with a force of...

(*c*) The force between two poles is...proportional to the...but.. proportional to...the distance between them.

3. The strength of an electromagnet depends upon the followings :

(*a*) Strength of the...

(*b*) Number of...

(*c*) Area of...

(*d*) Medium of the plane of...

13

Emission of Electrons

1. PHOTO ELECTRIC EFFECT

§13.01. Points to Remember.

(1) **Photoelectric effect.** It is the phenomenon of emission of electrons from the surface of a metal when light falls upon it. The electrons so ejected are called **"Photo electrons"**.

(2) **Photoelectric Cell.** It is an evacuated glass tube containing inside it a metal anode '*A*' and a cathode *C* as shown in Fig. 13.1. The anode and cathode are connected to two base pins through the base *B* of the tube. The cathode *C* is a concave surface coated with a photo-sensitive material like the oxides of calcium, ceasium or rubidium. The whole glass tube is blackened except for a small portion in front of the cathode.

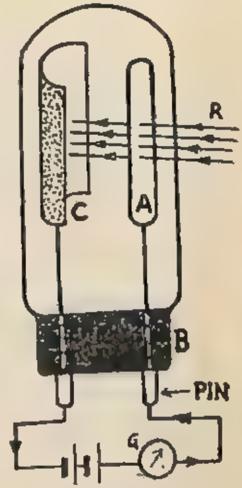


Fig. 13.1. Photo cell (in circuit).

§13.02. Demonstration Experiment No. 8.

Aim. To demonstrate the photo-electric effect.

Apparatus. A photoelectric cell, say tube No,884, a cell, a sensitive galvanometer, connecting wire and a torch or candle and a match box.

Procedure. (1) Make circuit connections as shown in Fig. 13.1.

(2) Allow the light to fall on the *"photo-sensitive"* surface of the cathode. Observe a deflection in the galvanometer. This deflection is due to electric current constituted by the '*photo electrons*' emitted from the cathode surface.

Conclusion. In photo-electric effect, the light energy is converted into electrical energy.

Note. In case a photo electric cell is not available then a photo-voltaic cell as

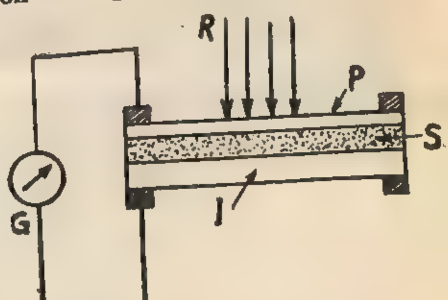


Fig. 13.2. Photo-voltaic cell.

shown in Fig. 13.2 (for which no external source of e.m.f. is required) may be used for demonstration purposes.

2. ELECTRONICS
DIODE AND TRIODE

§13.03. Points to Remember.

(1) **Thermionic Emission.** The process of emission of electrons from the surface of a metal heated suitably, is called *thermionic emission.* The number of electrons emitted from a metal surface depends upon (*a*) the temperature of the metal surface and (*b*) nature of the metal and (*c*) nature of the metal surface *viz.* whether the surface is clean or contaminated with impurities.

(2) **Vaccum Tubes.** These are usually glass tubes evacuated to very low pressure and contain a *metal wire* [*F* in Fig. 13.3 (*a*)] or metallic hollow cylinder [*C* in Fig. 13.4 (*a*)] which after getting heated, gives out electrons. These emitters of electrons are called **Cathode**. The usual materials for **cathode** are **tungsten**, thoriated **tungsten** (tungsten surface coated with thorium and carbon) or **oxide** cathodes (barium-strontium oxide). The vacuum tubes contain other electrodes also.

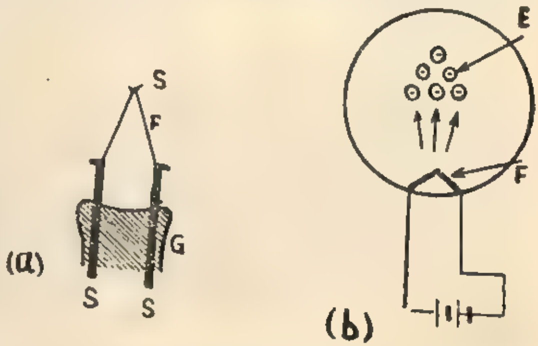
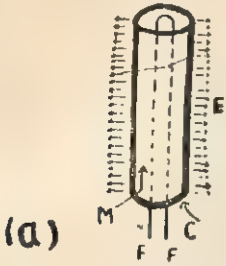


Fig. 13.3. (*a*) Directly heated cathode.. (*b*) Representation of directly heated cathode in a vacuum tube.

(3) **Cathode.** Depending upon the manner in which a cathode is heated, it may be either of the two categories as under :

(*a*) **Directly heated cathode.** In this type of cathode, a wire filament of tungsten is heated directly by passing a current in it with the help of a battery of about 6 volts as shown in Fig. 13.3 (*a*) and (*b*).

(*b*) **Indirectly heated cathode.** This type of cathode is a nickel hollow cylinder, the outer side of which is coated with suitable oxide. Inside the cylinder, along its axis, there is a filament, **F**, of tungsten in which the heating current is passed. The cylinder, **C**, is insulated electrically from the filament with the help of a mica sleeve **M** which allows only heat energy to pass. Thus in this type of cathode, the heating current passes in a separate wire and the cathode is heated **Indirectly** as shown in the Fig. 13.4 (*b*). The performance of an **indirectly heated cathode** is better and also its life is much longer than the life of **directly** heated type of cathode.



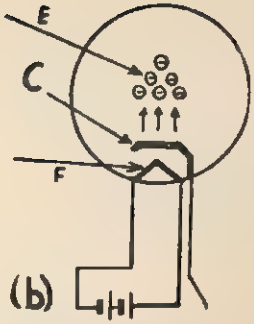


Fig. 13.4. (*a*) Indirectly heated cathode. (*b*) Representation of indirectly heated cathode.

§13.04. Demonstration Experiment No. 6.

Aim. To demonstrate diode and triode valves in the class and to explain their construction.

Apparatus. A diode valve of glass tube *e.g.* 6*H*6 or 5*Y*3*GT* a triode valve of glass tube *e.g.* 6*J*5.

Procedure. (*i*) Diode and triode tubes may be shown to the students by circulation amongst them.

(*ii*) The diagrams of diode and triode valves may be drawn on the blackboard.

(*iii*) The constructions may be explained as below.

Diode Valve. The diode is the simplest type of vaccum tube. It consists of a **cathode** *F* which serves as electron **emitter** and an **anode** *P* which acts as electron **collector** and surrounds the cathode as shown in Fig. 13.5. Both these elements are enclosed in an evacuated glass or metal tube. The **anode** is generally a metallic plate like nickel, a molybdenum plate. The construction of the cathode we have already discussed and, in this case, it may be either a **directly** or **indirectly** heated cathode. The plate is connected to the **base pin** *P* and the two ends of the filament are connected to the base pins *F* and *F* through the bakelite base *B* of the tube. The symbolic representation of a diode is shown in Fig. 13.5 (*b*).

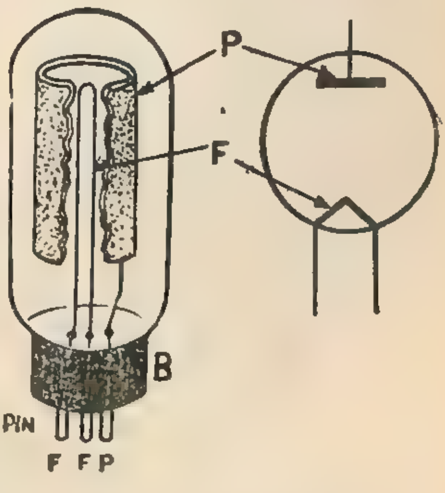


Fig. 13.5. A diode valve and its representation.

Triode Value. A triode valve consists of an evacuated glass or metal tube, inside which there are three electrodes fixed. These are the *cathode*, the *grid* and the *plate* or the *anode*. **Cathode** is either directly or indirectly heated type of thoriated tungsten metal and serves as an electron emitter. The cathode is surrounded by the **grid** which is usually, a few turns, of metal wire in a helical form as shown in Fig. 13.5 (*a*). The grid is surrounded by a metal hollow cylindrical tube called the **anode** or the **plate** *P*. The grid is nearer to the cathode than to the plate. The three electrodes inside the tube do not touch each other. The two ends of the filament are connected to two base pins *F* and *F*. The grid and plate are connected to base pins *G* and *P* respectively. Tube base is made of bakelite.

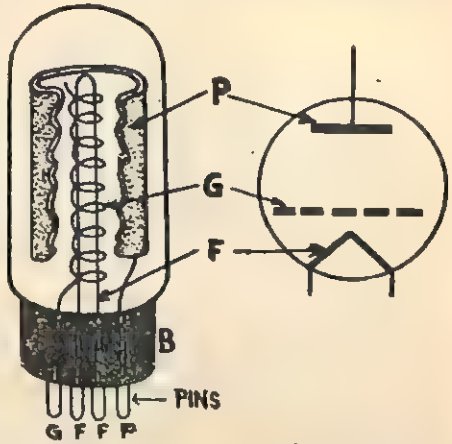


Fig. 13 6. A triode valve and its representation.

3. RADIO RECEIVER

§13.05. Points to Remember.

(1) **Transmitter.** The function of a radio-transmitter is to transmit the music or speech to a distant place. The sound waves of music or speech are converted into electrical **signals** with the help of a **microphone** This **signal** which is in the audio-frequency region (20 Hz to 20 KHz) is **mixed** with a high frequency (usually more than 500 KHz) wave called the **carrier wave**. Due to the mixing of the signal with the carrier wave, the mixed wave can travel through a much longer distance, say many hundreds kilometres. The mixed wave is usually called "Amplitude Modulated Wave".

(2) **Receiver.** It is an electronic device to catch the Amplitude Modulated wave transmitted from radio station and then to select out the *signal* by rejecting the *carrier* wave from the *mixed* wave. The receivers can be of two types (*a*) crystal receivers and (*b*) vacuum tube receivers as discussed below.

§13.06. Group Activity No. 4 (*a*).

Aim. To design a **crystal** receiver.

Apparatus. A crystal diode (*IN* 34), headphone, a condenser of fixed capacity of ·02 μf, a variable tuning condenser (Gang condenser) of 0 to 300 p.f. capacity, broadcast ferriloop antenna coil

which is commonly available from a radio-parts dealer, 10 metres of copper wire, insulating rings, two wooden or bamboo poles, connecting wires, a wooden board soldering wire and soldering material.

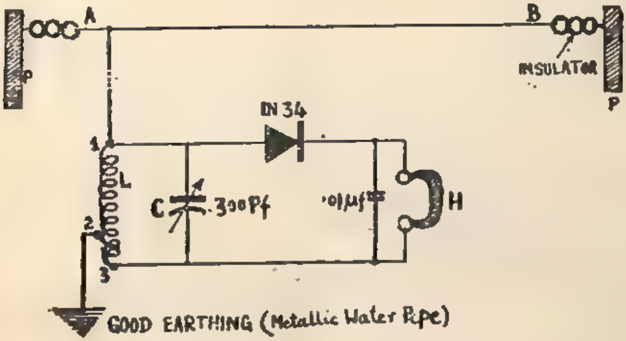


Fig. 13.7.

L→Ferriloop coil.

C→Gang condenser of 300 *pf.*

Procedure. (*i*) Draw the circuit diagram as shown in Fig. 13.7 on a wooden board with the help of suitable paint.

(*ii*) Drill suitable holes in the board to fix the components. The components should be fixed in such a way that the length of the connecting wires is minimum.

(*iii*) Now solder the joints with the help of soldering iron. For the technique of soldering read chapter 15.

(*iv*) Now raise the outdoor antenna of 10 metre wire *AB* with the help of the insulators and two bamboo poles.

(*v*) Connect the headphone as shown, *H*, in the circuit diagram. Now tune the gang condenser until a station is heard.

§13.07. Group Activity No. 4 (*b*).

Aim. To design a vacuum tube (one valve) receiver.

Go to a radio-parts dealer with the circuit diagram of Fig. 13.8 and buy the components. Now assemble the receiver on a wooden board. In place of D C. source of 250 volts a power supply may be used. The heating current for the filament *H*, *H* may be from the 6.3 volts output of the power supply.

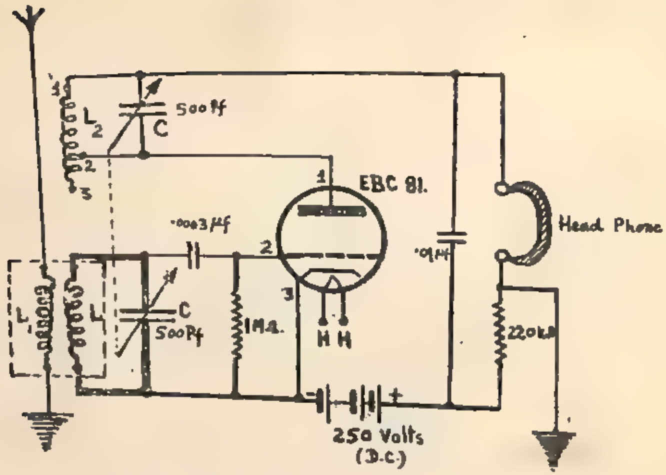


Fig. 13.8. A simple one valve radio-receiver.

4. POWER SUPPLY OR RECTIFIER

§13.08. Points to Remember.

(*i*) **Alternating Current** (A.C.). An electrical current which changes in *direction* and *magnitude* with respect to time is called an alternating current.

(*ii*) **Direct Current** (D.C.). An electric current which flows in the same direction with a constant magnitude continuously is called a direct current.

(*iii*) **Pulsating D.C.** A current which changes in magnitude but does not change in direction is called a pulsating or fluctuating D.C.

(*iv*) **Power Supply or Rectifier.** It is a device which converts A.C. into D C. A diode valve or a crystal diode can do this job as discussed below.

§13.09. Group Activity No. 5.

Aim. To design a diode rectifier.

Apparatus. Diode valve (5Y3), an octal socket, a transformer having the turn ratio of 1, an electrolytic condenser of 32 μf capacity and 450 volts (D.C.) as the working voltage, a 10 $k\Omega$ wire-wound resistance of 10 watts. A D.C. voltmeter (300 volts), connecting wire, soldering iron and other accessories for the fitting.

Procedure. (*i*) Draw the circuit diagram of Fig. 13.9 on a wooden board with a suitable paint.

(*ii*) Make suitable holes on the board to fix the components. For fixing the diode valve an octal base should be fitted.

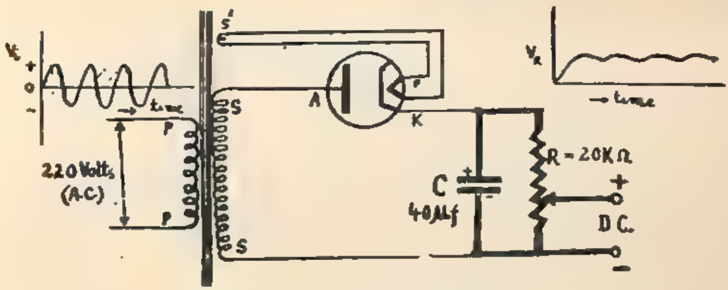


Fig. 13.9. A half wave rectifire.

(*iii*) Solder the joints properly.

(*iv*) Connect the two ends of a D.C. voltmeter (300 volts) across the A.C. mains points. You will observe no deflection of the pointer.

(*v*) Now connect the primary, *PP*, of the transformer to the 220 volt A.C. mains and then switch it on.

(*vi*) Connect the D.C. voltmeter across the resistance *R* such that the positive of the voltmeter is connected to the cathode point. You will now notice a voltage recorded by the voltmeter which indicates that the circuit assembled has converted the A.C. voltage into a direct voltage across *R*.

14

Heat and Energy

INTERNAL COMBUSTION ENGINES

§14.01. Points to Remember.

(*i*) **Internal Combustion Engines.** In these engines the energy is provided by burning the fuel *inside* the engine in contrast with the steam engines in which the burning of the fuel (water) takes place in a *separate* boiler.

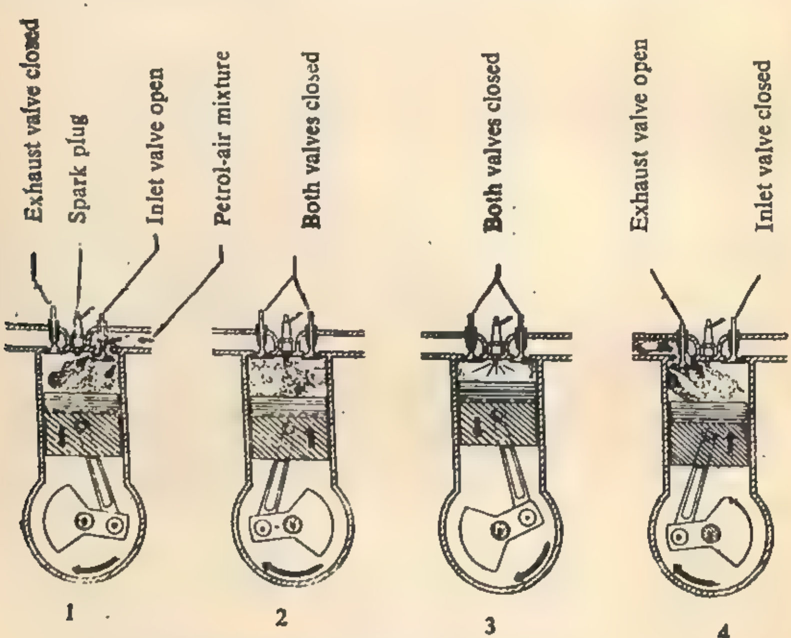


Fig. 14.1. The Petrol Engine

1. **Induction.** Petrol-air mixture enters the cylinder by atmospheric pressure as piston descends.
2. **Compression.** Mixture is compressed and spark ignites it just before top of stroke.
3. **Power.** Mixture burns and expands, giving energy to push the piston downwards.
4. **Exhaust.** Burnt gases expelled out through exhaust port.

(*ii*) Fig. 14.1 along with its captions illustrates the functioning of a petrol engine. The four essential stages occurring in two revolutions of the engine are referred to as the four strokes.

(*iii*) For the initial running of the engine a separate motor is required to start the Induction and the compression strokes. Once the engine is running, part of its rotational kinetic energy stored up in its heavy flywheel provides the work required for the subsequent induction, compression and exhaust strokes.

(*iv*) Read about the "diesel engine" which is another category of internal combustion engine from your theory text book.

§14.02. Group Activity No. 5.

Aim. To design the model of a petrol engine which is an internal combustion engine.

Apparatus. A wooden box, three toothed wheels such that the diameters of W_2 and W_2 are equal and that of W_1 is half of the diameter of W_2, a crank and shaft arrangement, S, a piston P fitted in a tube, a bulb of 6 volts, a battery of 6 volts and other accessories as indicated in the diagram of Fig. 14.2.

Assembly. (1) Fix the three toothed wheels (W_1, W_2, and W_2) such that their centres are on the same line and their teeth are interlocked properly as shown in Fig. 14.2. Join the crank and shaft arrangement (S) to the piston (P) with a metal rod (R). Attach two calm (C) to the wheels W_2 and W_2.

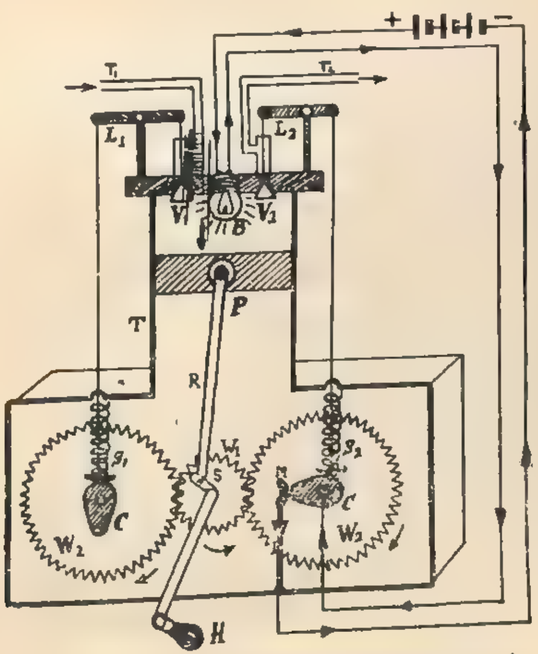


Fig. 14.2. Model of an Internal Combustion Engine.

(2) A wooden cap is fitted on the upper end of the tube (T) containing the piston (P). This cap contains two valves (V_1) and V_2 and a bulb (B) whose electrical connections also are shown in Fig. 14.2. This bulb (B) represents the spark plug of a petrol engine. The two valves (V_1) and (V_2) are operated by the levers (L_1) and (L_2) which are controlled by rods - resting on the calm (C) and (C) with the help of springs (S_1) and (S_2).

(3) The stage shown in the diagram of Fig. 14.2 represents the *power stroke i.e.* when the bulb glows. The bulb glows only when the calm of the right hand wheel W_2 makes contact with the metal strip (M).

(4) The diameters of the wheels W_2 and W_2 are equal and twice the diameter of the wheel W_1 so that W_2 and W_2 complete only one rotation while W_1 completes two rotations. The relative d rection in which the three wheels rotate is indicated by arrows.

(5) The tubes T_1 and T_2 represent the carburettor and the exhaust respectively.

Operation. Rotate the handle (H) attached to the wheel (W_1) and explain the (i) induction (ii) compression (iii) power and (iv) exhaust strokes of the engine. All the four strokes are completed for two revolutions of the wheel W_2 containing the calm and hence the diameters of W_2 and W_1 are in the ratio of 2 : 1.

2. ENERGY

§14.03. Points to Rememeber.

(1) **Energy.** *Capacity of a body for doing work is called its Energy.* It is measured by the amount of work that a body can do.

(2) **Forms of Energy.** Energy in nature exists in various forms such as mechanical, light, sound, electrical, chemical, magnetic and atomic energy. These different forms of energy are inter-convertible. During the course of inter-conversion of energies, a law which is always obeyed is the **Law of Conservation of Energy.**

(3) **Mechanical energy.** This type of energy may be in two forms : **Kinetic** and **Potential.**

(i) **Kinetic Energy.** *The energy possessed by a body by virtue of its motion is called kinetic energy.* If a body of mass 'm' is moving with a velocity 'v', then its kinetic energy is given by $\frac{1}{2}mv^2$.

(ii) **Potential Energy.** *The energy possessed by a body by virtue of its position or configuration is called Potential energy.* A body occupying an elevated *position* possesses potential energy.

If a helical spring is compressed then it possesses potential energy due to change in its *configuration.* The potential energy stored in a body of mass 'm' which is raised through a vertical height 'h' is of amount m.g.h.

Like other forms of energy, mechanical energy is also inter-convertible in its two forms. To demonstrate the interconversion of kinetic and potential energies, let us consider following experiment.

§14.04. Demonstration Expt. No. 3.

Aim. To demonstrate the change of kinetic energy into potential energy and *vice versa.*

Apparatus. A pendulum bob or a stone piece, thread and a stand.

Procedure. (*i*) Tie one end of the thread (about one metre long) to the stone or the bob, the other end of the thread being fixed tightly to the stand kept on a table. This arrangement is now a "simple pendulum".

(*ii*) The "simple pendulum" rests in such a position that the thread is vertical as shown by the position *A* in Fig. 14.3. This position is called its mean position. The bob is now displaced from its mean position *A* to another position *B* and then it is released. Observe the to and fro motion of the bob about its mean position *A*.

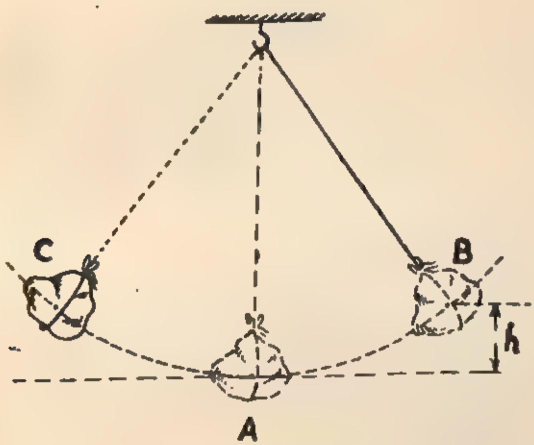


Fig. 14.3. An Oscillating Stone.

Explanation. When the bob is displaced to the position *B*, its potential energy increases by an amount m.g.h. At this position it has no kinetic energy because it is at rest. When the bob is released from the position *B*, it starts moving towards its mean position *A*. In doing so, it gains kinetic energy but its potential energy with respect to the position *B* is decreased. The *decrease* in the potential energy appears in the form of kinetic energy of the bob. When the bob comes back to the mean position *A*, its potential energy is minimum and kinetic energy is maximum because at this position the

velocity of the bob is maximum. The potential energy m.g.h. of the bob at the position B has now been completely converted into kinetic energy at the position A. When the bob goes on the other side of the mean position *i.e.*, towards C, the kinetic energy starts getting converted into potential energy. The kinetic energy is completely converted into potential energy again at the other extreme position C. In this way for to and fro motion of the bob about its mean position, the interconversion of kinetic and potential energy takes place.

QUESTIONS

Complete the following sentences by picking suitable alternative from those within the brackets :

(*a*) Steam-engine is an.........combustion engine. (internal, external)

(*b*) Petrol-engine is an...... ..combustion engine. (internal, external)

(*c*) Heat is......... (degree of hotness, a form of energy)

(*d*) When we rub the palms of our hands together briskly, then the......... produced is due to the conversion of.........energy into.........energy. (heat, mechanical)

(*e*) The efficiency of a steam engine is.........than the efficiency of a petrol engine. (greater, smaller)

Elementary Training in Soldering

§15.01. Points to Remember.

(*i*) *Soldering.* It is the process used to join metallic surfaces.

(*ii*) *Soldering Iron.* It is an electrical instrument used for joining two or more ends of metal wires with the help of *solder* and the *flux.* The essential parts of a soldering iron are indicated in Fig. 15.1(*a*). The tip of the soldering iron which is made of copper is heated electrically.

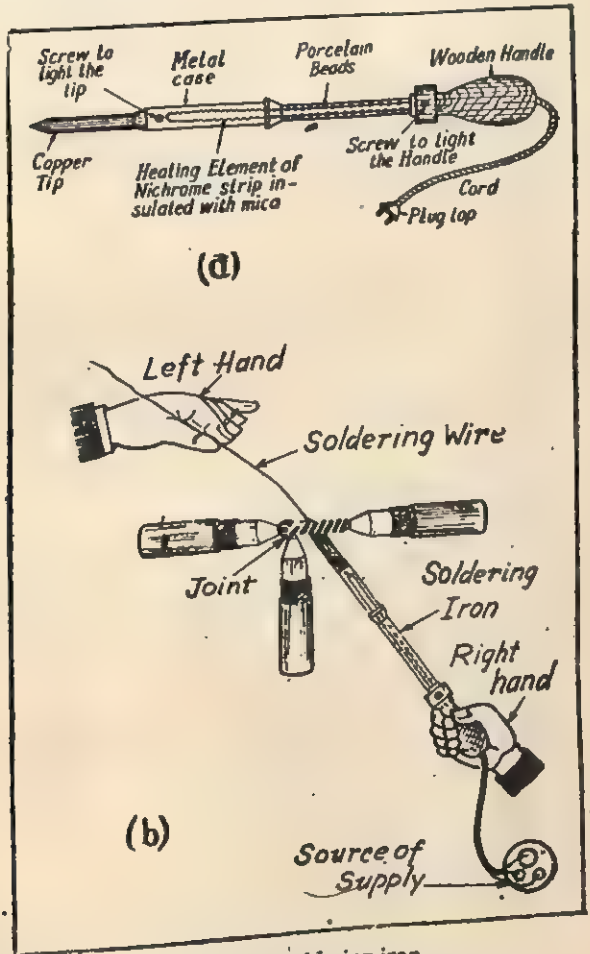


Fig. 15.1. (*a*) Parts of a soldering iron.
(*b*) Illustration of the soldering process.

(*iii*) *Solder* or *Soldering Material.* Most of the soft solders are alloys of tin and lead. But for special joints of different metal wires suitable solders are used as indicated below :—

Metal to be joined	*Solder used*
(*i*) Copper	alloy of Tin and Lead
(*ii*) Aluminium	alloy of Tin and Cadmium or alloy of Tin and Zinc

For an alloy of Tin and Lead, the suitable temperatures for soldering are above 165°C because at these temperatures the solder of copper, melts properly. For electrical connections of copper wires, solder of 60/40 (Zn/Pb) is suitable, but for robust fixing solder of 40/60 is suitable.

Flux. Before the soldering the cleaning of the surfaces to be joined must be ensured. In order to clean the surfaces and to avoid the effect of oxidation coating, cleaning materials called *Flux* are used. The flux depends upon the nature of the metal to be joined as detailed below :

Metal to be joined	*Flux used*
(*i*) Brass, Copper, Tin	Rosin
(*ii*) Lead	Tallow, Rosin
(*iii*) Iron, Steel	Borax, Sal Ammonniac
(*iv*) Galvanized Iron, Zinc	Zinc Chloride
(*v*) Aluminium	Stearine, special flux

§ 15.02. Pupil's Activity No. 6.

Aim. To solder a joint of two copper wires or cables.

Apparatus. Soldering Iron (65 watts), Flux (rosin), solder wire (alloy of [illegible] and lead), a small piece of sand paper, a cutting plier and pocket knife etc.

Procedure.

(*i*) Clean the tip of the soldering iron with sand paper such that the copper colour is brightly visible.

(*ii*) Switch on the soldering iron.

(*iii*) Scratch the insulation coating on the tips of wires or cables with a knife and sand paper.

(*iv*) Dip the tip of the soldering iron in the flux when it is hot and then put solder material on the tip such that a small amount of molten solder remains on the tip.

(*v*) Now dip the cleaned end of the wires to be joined into the flux and then paste the soldering material on them with the help of the iron tip.

(*vi*) Now join the ends and twist them as shown in Fig. 15.1(*b*). Now heat this joint with the iron tip and simultaneously apply the solder as detailed in Fig. 15.1(*b*).

(*vii*) Now remove soldering iron from the joint after the joint is completely wet with the molten solder.

(*viii*) Do not move the soldered joint until the melted silvery coloured solder has turned into a dull white colour. The white colour indicates that the solder has become hard.

Precautions

(*i*) Clean well the tip of the soldering iron and the wire ends to be joined with sand paper.

(*ii*) Tcuch the joint with hot tip of the soldering iron until enough heat is produced so that the solder melts and runs like water into the joint.

(*iii*) Do not allow the hot tip to touch any other part of insulated wires.

(*iv*) Do not overheat the soldering iron because it causes rusts to form more quickly on the iron.

(*v*) Do not drop too much solder on the joint.

(*vi*) Always place the hot soldering iron on a metal rack when not in use.

(*vii*) Disconnect the soldering iron from the mains when the soldering process is complete.

Note. It is often useful to have a tube of quickfix and a set of Aradite which are adhesive pastes. These adhesives can join any two surfaces where electrical ccntact is not required. For instant fixing quickfix is used and for permanent and hard fixing a paste of Araldite is used.

16

Elements of Workshop Practice

§16.01. Description about some common tools and their uses

(1) **Screw Driver.** It is used to rotate screw by fitting it in the slot of the screw-head. It usually consists of a steel rod fixed

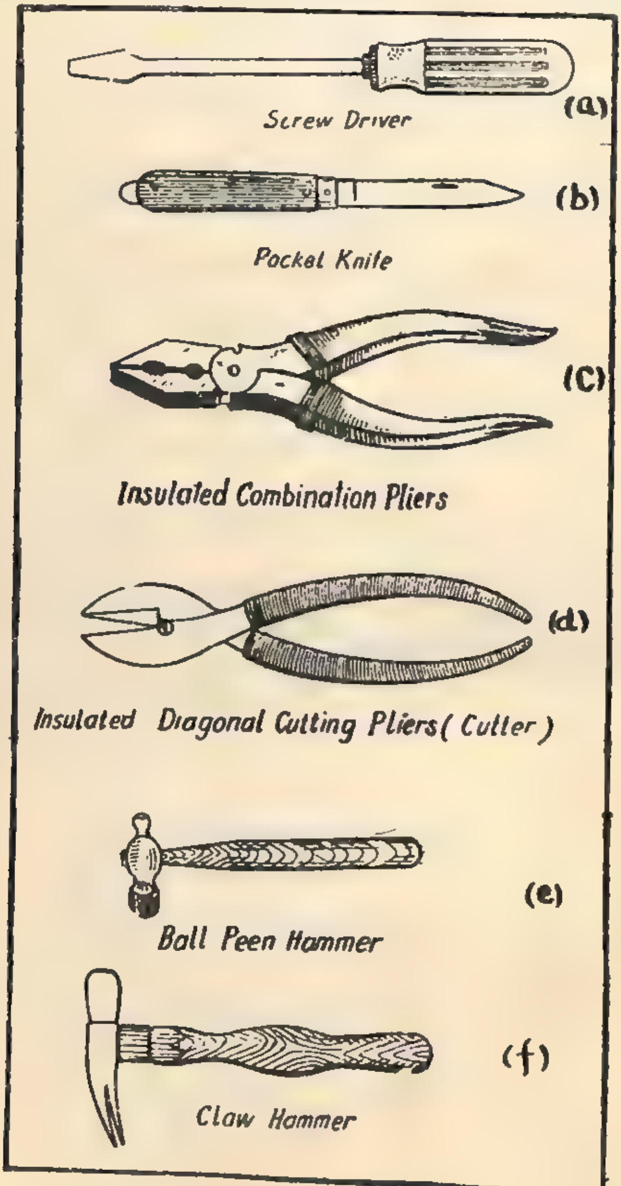


Fig. 16.1. Common Workshop Tools.

to a wooden or a metallic handle as shown in Fig. 16.1 (*a*). The steel rod is tapered to a flat end.

(2) **Pocket Knife.** A folding type of pocket knife is shown in Fig. 16.1 (*b*). It is used to peel the insulation of a wire or to cut things like wire, thread etc.

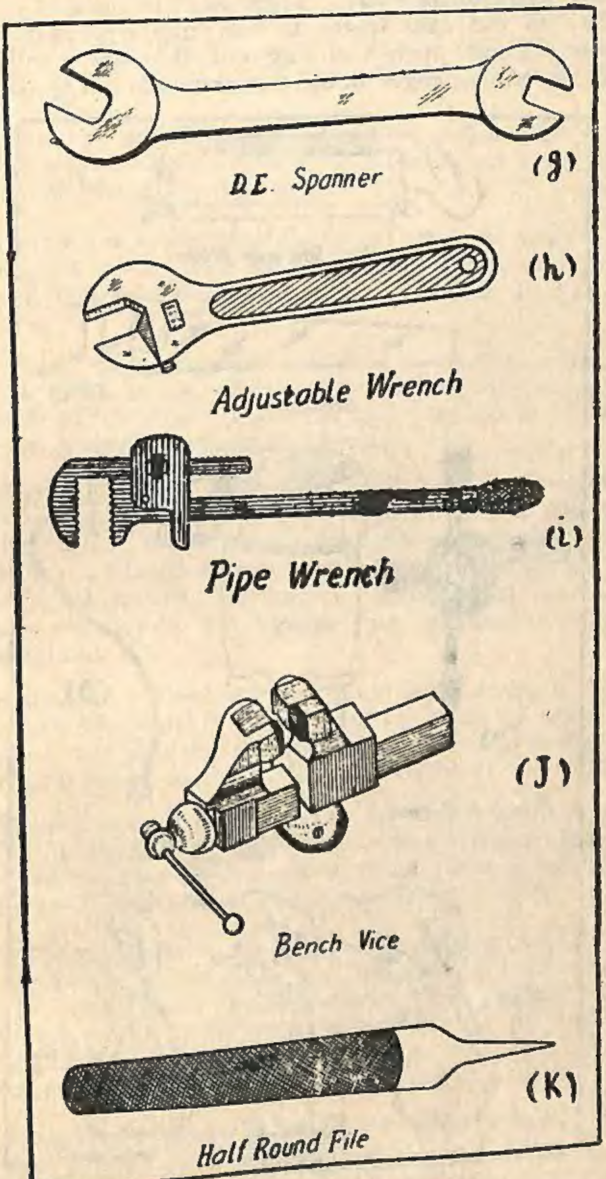


Fig. 16.1. (Continued)

3. Pliers.

(*a*) *Insulated Combination Pliers.* These pliers are used for cutting or bending wires. These are also used for holding or gripping operation by hand. It is made up of tool steel. It has snab-nosed jaws and cutting edge as shown in Fig. 16.1 (*c*).

(*b*) *Diagonal cutting pliers.* These pliers are used to cut off the wires closed to the ends where the combination pliers do not serve the purpose. These pliers can also cut thin and small sheets of metal. It has cutting edges on one side as shown in Fig. 16.1 (*d*).

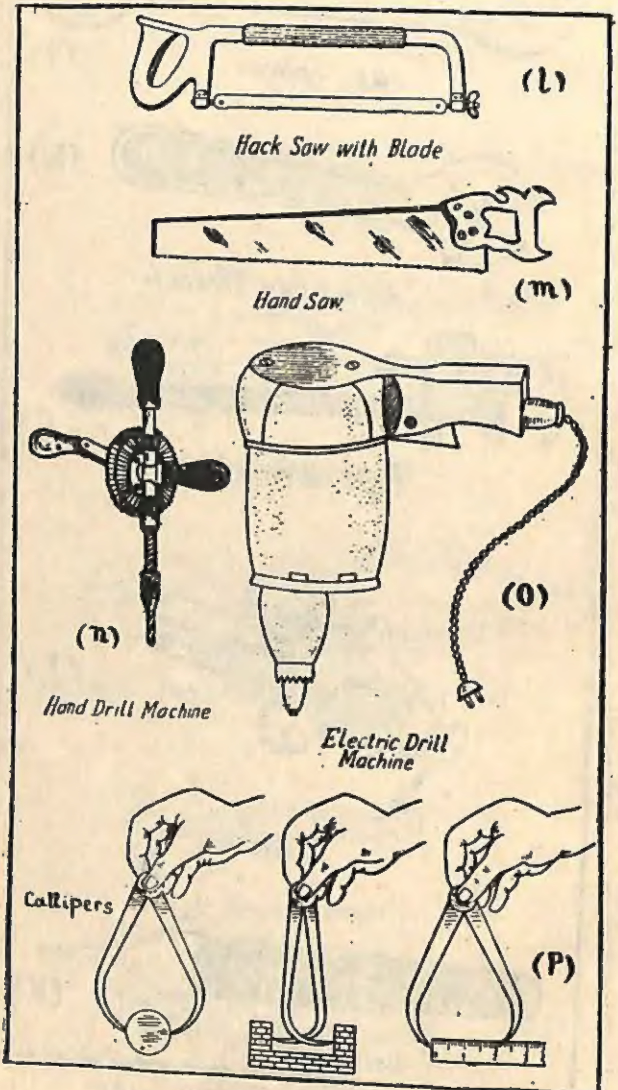


Fig. 16.1. (Continued)

(4) **Hammers.** Hammers are used for fixing nails, for flattenning metals and for straightening articles etc. Hammers consist of a wooden or metallic handle fitted in a suitable metal block. The two common types of hammers are (*a*) *Ball Peen hammer* and (*b*) *Claw Hammers* as shown in Fig. 16.1 (*e*) and (*f*) respectively. The *Claw Hammers* can also be used to remove the nails from the places where it is fixed.

(5) **Spanner and Wrench.** Spanners are used for tightening or loosening nuts and bolts. These are made of cast steel and have fixed jaws as shown in Fig. 16.1 (*g*).

The wrench is a kind of single ended spanner with adjustable space between its jaws. This is achieved by making one of the jaws movable and fixed in different positions as shown in Fig. 16.1 (*h*) and (*i*).

(6) **Vice.** It is a common tool used in workshop for holding works. It is shown in Fig. 16.1(*j*). The body and the sliding jaws of vice are made of cast iron. The other parts are made of steel. It may be either a *portable* type or *bench* type.

(7) **Files.** Files are used almost in all metal and wood works. These are made of hard steel and have large number of sharp edges or teeth [Fig. 16.1(*k*)] which remove fine chips of material. They are of different shapes. **Flat** files are particularly used to make the surfaces of metal or wood smooth. **Round** or **half-round** files are used to smoothen the holes. **Triangular** files are used to sharpen the teeth of hand saw.

(8) **Hacksaw.** These are used to cut metal rods, bars, pipes, etc. It has metallic frame in which a narrow blade of good quality tempered alloy steel with set teeth, is fitted as shown in Fig. 16.1(*l*). The frame has a means to apply tension in the blade.

(9) **Hand Saw.** It is a cutting tool used in wood works. It consists of a thin metal blade which has a series of sharp teeth on one edge. Each tooth cuts or tears away a small piece of wood. The blade is fixed to a wooden handle as shown in Fig. 16.1 (*m*).

(10) **Drill Machines.** It is a tool for making holes in wooden or metallic pieces. These machines are designed to hold steel twist drills and to rotate them freely. Rotation can be either by hand (hand drill machine) or by electrical power (electric drill machine). Different sizes of drill bits can be fitted in these machines. The two kinds of drill machines are shown in Fig.16.1 (*n*) and (*o*).

(11) **Simple Callipers.** This instrument consists of two pointed arms of metal hinged together as shown in Fig.16.1(*p*). These are used to measure internal and external diameters or distances.

N.B. There are frequent chances of cuts and scratches on the student's body with the tools in the beginning of workshop practice.

Therefore every laboratory or workshop must have a **First Aid Box** containing at least burnol, mercurocrome, band aids, dressing material etc.

§16.02. Precautions in the Use of Tools

(1) Do not carry a sharp edged tool, like a knife unshielded in pocket. Whenever you are passing a sharp edged tool to another person, pass its handle first and not the edged portion first.

(2) Do not place your fingers or hands in the path of the motion of a cutting tool.

(3) While starting a cut with a saw it should be handled carefully. It is necessary to guide the saw with fingers and thumb of the left hand while starting the cutting process. Carelessness here may cause serious injury.

(4) Do not use a hammer with shaky or broken handle. Hammer must be fastened securely to the handle before its use.

(5) Do not leave the tools on the top of a ladder or at places above your head. There is always a danger of falling of the tools.

(6) There is a common saying, "a sword cannot do the job of a needle and *vice-versa*". This is exactly true in the use of the tools. Use the tool for the purpose for which it is designed.